Analysis of Montana Nutrient and Biological Data for the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS)

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EXECUTIVE SUMMARY

Montana Department of Environmental Quality (MDEQ) has been working identify appropriate criteria for nutrients in streams for the past ten years. This report presents results of a recent project to develop nutrient endpoints in Montana streams using periphyton and benthic macroinvertebrates as indicators of aquatic life sensitivity and integrity. The purpose of this report is to describe nutrient conditions in Montana streams, present the analyses of nutrient-biotic relationships, and suggest ranges of potential nutrient criteria. The endpoints developed here for nitrogen and phosphorus are in support of the State's efforts and should only be used as components of a broader analysis.

EPA encourages states to explore the stressor-response relationships when establishing criteria that are protective of aquatic life. Stressor-response approaches refer to analytical techniques that derive candidate endpoints by exploring and identifying thresholds in the relationships between response variables and nutrient concentrations. Typical response variables include biomass, assemblage metrics, and aquatic life use indicators or biocriteria indicators. The value of these indicators is their direct linkage to aquatic life use designations. Therefore, they provide a way to connect nutrient concentrations directly to aquatic life use protection.

The analytical techniques for relating stressors and responses (nutrients and biota) included correlation analysis, Change-point Analysis, Species Sensitivity Distributions, and Propensity Scores. We describe these techniques and the relative importance of each, including the advantages and limitations that lead to differential weighting of potential nutrient criteria analyses. The distribution of nutrient concentrations in ecoregional classes were also used as an indication of background nutrient conditions, independent of biological responses.

Correlation analysis showed that multiple metrics of both periphyton and macroinvertebrate assemblages were related to nutrients. Propensity score analysis showed that after accounting for covariates, effects of total phosphorus (TP) on periphyton were evident at TP levels less than 0.030 mg/L. At higher levels, TP did not appear to be controlling periphyton signals.

The combination of results from multiple stressor-response analyses and reference distributions resulted in wide ranges of potential nutrient criteria (**Table ES-1**). Potential nutrient criteria in the mountainous regions were generally lower than those in the plains. The median of the multiple criteria is a reasonable indication of the corroboration among analyses. The quartiles give further indication of the range of criteria that might apply. Minimum and maximum values resulting from the analyses were discounted as uncorroborated results.

Table ES-1. Median and quartile ranges for potential nutrient criteria in Montana regions.

Total Nitrogen			Total Phosphorus		
25th %ile	median	75th %ile	25th %ile	median	75th %ile
Mountains - Idaho Batholith, Northern Rockies, Canadian Rockies					
0.114	0.139	0.285	0.004	0.010	0.016
Middle Rockies					
0.247	0.401	0.515	0.013	0.021	0.030
Low Valley (subset of Middle Rockies)					
0.419	0.660	0.916	0.042	0.048	0.053
Plains					
0.619	1.115	1.32	0.027	0.077	0.125

While there are caveats and further research needs described in the report, the potential nutrient criteria summarized here are reasonable thresholds derived from multiple analyses with reference distributions and stressor-response associations with two biological assemblages. Because we rely on corroborated results and central tendencies of multiple analyses, extreme values can be recognized and discounted, decreasing the chances of erroneous criteria recommendations.

Acknowledgements

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1 Introduction

Since the late 1990's, EPA has encouraged states to adopt numeric nutrient criteria. Montana Department of Environmental Quality (MDEQ) has been working identify appropriate criteria for nutrients in streams for the past ten years. As a result of these efforts, MDEQ is finalizing draft numeric nutrient criteria intended to protect beneficial stream uses, for example aquatic life. This report presents results of a recent project to develop nutrient endpoints in Montana streams using benthic macroinvertebrates and periphyton as indicators of aquatic life sensitivity and integrity.

The purpose of this report is to describe nutrient conditions in Montana streams, present the analyses of nutrient-biotic relationships, and suggest ranges of potential nutrient criteria. The endpoints developed here are in support of the State's effort and should only be used as components of a broader analysis.

1.1 Nutrients

Nutrients occur in streams naturally and can be greatly increased due to human activity. In this study we focus on nitrogen and phosphorus because these nutrients can limit primary production and are readily measured. Other nutrients are usually only required in trace amounts for plant growth and are rarely limiting to production. Therefore, increases in nutrients other than nitrogen and phosphorus may be evident with increased human disturbance, but they are not suspected of causing changes in the primary and secondary producers.

Human activities can cause increases in nutrient concentrations in streams through a variety of pathways. These include, but are not limited to, fertilizer application, soil and vegetative disturbance, partial treatment of wastewater, and animal production. Increases in major nutrients are often associated with increases in other pollutants and stressors. The interaction of multiple stressors can cause amplified or buffered effects on responding organisms. This phenomenon was partially explored in this analysis, though the emphasis remains on the interaction between major nutrients and biotic responses.

1.2 Aquatic Life

Nutrients are known to limit or encourage growth and proliferation of primary producers. In streams, these would include periphyton and aquatic macrophytes. Periphyton (including diatoms) are ubiquitous in streams and can be sampled consistently and are therefore may be acceptable indicators of nutrient conditions. The periphyton species are responsive to stressors other than nutrients, especially in the West (Stevenson 2008), but these confounding factors may be recognized and perhaps even factored out of descriptive stressor-response relationships.

Benthic macroinvertebrates interact directly with periphyton, and therefore, indirectly with nutrients. There may be some direct nutrient – macroinvertebrate response pathways, but these are not well defined. The indirect effects are through pathways of respiration and food availability. Periphyton provide oxygen when photosynthesizing, but can deplete oxygen as well, when microbes respire in the decay of excessive periphyton, caused by excessive nutrients. Thus, nutrients have an indirect effect on macroinvertebrates through periphyton and the oxygen supply. Macroinvertebrates can graze and inhabit periphyton communities. Some grazers may prefer certain types of periphyton. Excessive periphyton can also degrade macroinvertebrate habitat for those organisms that require substrates with sparse algal growth. Therefore, the indirect effects of nutrients on benthic macroinvertebrates, through periphyton, can cause varied responses in the macroinvertebrate community. In addition, these interactions can occur in both directions – with macroinvertebrates effecting periphyton through selectively grazing or to a degree that affects nutrient uptake from the water column. Benthic macroinvertebrates are responsive to many stressors other than nutrients, and the possible confounding effects should be factored out, when they are recognizable.

1.3 Natural Variability

Natural nutrient concentrations can be inferred from conditions observed in streams with minimal human activity at the site and in the catchment. These are referred to as the reference conditions. Reference nutrient conditions are subject to unavoidable human activities (such as atmospheric deposition), availability of suitable reference sites, and adequate recognition of natural variability. Reference sites were identified by MDEQ through a rigorous process that assessed site and catchment conditions using remotely sensed data and field observations (Suplee et al. 2005).

Nutrient concentrations in Montana streams are shown to have relatively homogenous concentrations within homogenous landscape types. The ecoregions of Montana (Woods et al. 2002) were used to define distinct landscape types and are shown, at level III and IV, to be meaningful stratification tools (Varghese and Cleland 2005). Benthic macroinvertebrate assessments in Montana are made within three bioregions – groupings of sites with similar biological expectations that are defined by ecoregions and site elevation (Jessup et al. 2006). In Montana, the three macroinvertebrate bioregions are: 1) mountains, 2) low valley; and 3) plains. Analyses were distinguished by bioregions or individual ecoregions when sufficient data existed.

1.4 General Approach

EPA encourages states to explore the stressor-response relationships when establishing criteria that are protective of aquatic life. In EPA's draft guidance on Empirical Approaches for Nutrient Criteria Derivation (USEPA 2009), several methods for evaluating stressor-response relationships are presented. Stressor-response approaches refer to analytical techniques that derive candidate endpoints by exploring and identifying thresholds in the relationships between response variables and nutrient concentrations. Typical response variables in the context of nutrient endpoint development include biomass and assemblage metrics (e.g., percent nutrient sensitive diatoms) and aquatic life use indicators or biocriteria indicators (e.g., trophic state indices, algal multimetric indices, or invertebrate multimetric indices). The value of these indicators is their direct linkage to aquatic life use designations. Therefore, they provide a way to connect nutrient concentrations directly to aquatic life use protection.

The approaches implemented in this analysis were adopted to take advantage of available data and to produce robust results using a combination of well-established and exploratory analytical techniques. The focus of the analysis was on the major nutrients, nitrogen and phosphorus, as they relate to two indicator assemblages, periphyton and benthic macroinvertebrates.

The analytical techniques for relating stressors and responses (nutrients and biota) included correlation analysis, Change-point Analysis, Species Sensitivity Distributions, and Propensity Scores. We describe these techniques and the relative importance of each, including the advantages and limitations that lead to differential weighting of potential nutrient criteria analyses.

1.5 Data Description

The data used in these analyses were provided by Montana DEQ and included three databases: nutrients, macroinvertebrates, and periphyton. Each database included data from throughout the state that were identified with a Station ID. The Station ID was used to link information among databases. Reference sites were identified by corroboration of designations in the nutrient database, in the benthic macroinvertebrate database, and in a separate list provided by DEQ (Feldman personal communication).

Nutrient Database: The nutrient database included more than 200,000 records of nutrient concentrations in streams. The nutrients recorded were related to nitrogen (ammonia, nitrate + nitrite, TKN, and total nitrogen), phosphorus (soluble reactive phosphorus, total dissolved phosphorus, and total phosphorus) and ancillary analytes (pH, specific conductance, temperature, turbidity, and dissolved oxygen). The primary nutrient data were aggregated into groups of similar measures (Suplee et al. 2007). The uniformity of measures across sampling agencies was confirmed prior to this simplification. For these analyses, “non-detect” data points were given a value equaling 50% of the detection limit. Endpoints recommended in USEPA guidance (USEPA 2000a, USEPA 2000b) include Total Nitrogen, TKN, Total Phosphorus, and Soluble Reactive Phosphorus. Additional water quality variables were later retrieved from STORET. These additional variables included metals, dissolved oxygen, total suspended solids, biological oxygen demand, and sulfate.

Macroinvertebrate Database: DEQ stores their macroinvertebrate database in the STORET/WQX database. The Ecological Data and Application System is used to generate macroinvertebrate indicators of water quality (Montana Department of Environmental Quality 2006). EDAS contains raw macroinvertebrate taxa lists, Operational Taxonomic Units (OTUs), calculated indicators (metrics, multimetric indices [MMIs], and Observed/Expected [OE] scores) for the majority of sites, and predictor variables used to determine the site classification. Sample collection methods, indicator metrics, and indices used in this analysis are as described by DEQ (Jessup et al. 2006). About 1080 samples, collected from 1032 stations using 5 different methods were found with matched macroinvertebrate and chemistry variables.

One benthic macroinvertebrate sample was compared to average site chemistry from samples collected within 30 days of the benthic sample. If multiple benthic methods were used on a single date, a preferred method was selected, with preferences as follows: Kick > Targeted Riffle > Reachwide > other. The preferences were established to maximize sample size, increasing the likelihood of analyzing the complete stressor gradient. Large benthic samples were artificially re-sampled to 300 organisms to reduce sample size effects on metrics. OTUs were generally at the genus taxonomic level. We analyzed metrics and indicators with proven responses to stress (MMI metrics, MMI scores, and OE scores). Feeding group metrics and the Trichoptera taxa metric were added because they were suspected of having some response to nutrients.

Macroinvertebrate data were analyzed by ecoregion, bioregion, and sampling method. Opportunities to aggregate samples collected by different methods were explored and samples from multiple methods were pooled when the results of each method overlapped in stressor-response biplots. Separate analyses were conducted for methods that could not be aggregated because of non-overlapping data points in the biplots.

Periphyton Database: Periphyton data in Montana have been collected through numerous DEQ projects and by other entities. Roughly 1400 algal samples were collected during 2000 to 2008 over the summer sampling season (June - September). Most of these samples were compiled by DEQ. Additional data from EMAP-West were added to a single periphyton database. Potential bias that may be introduced by different sampling protocols was assumed to be minimal.

Ninety-nine (99) periphyton metrics of interest were calculated in the relational database and included: metrics described by Porter et al. (2008), by Stevenson et al. (2008), the mountain nutrient increaser developed by Loren Bahls (provided by Montana DEQ), Kelly and Whitten pollution tolerance index (1995), Van dam metrics (1994), and periphyton indices developed by Potapova and Charles (2006).

2 Methods

2.1 Nutrient distribution descriptions

The distributions of nutrient concentrations served as a baseline description of nutrient conditions throughout Montana. The distribution percentiles in different sub-sets of the data can be used to describe general nutrient conditions by nutrient species, ecoregion, or reference status of the sites. These standards have long been established (U.S. EPA 1998, Barbour et al. 1999) and are now accepted as practical guidelines for describing reference expectations.

2.2 Correlation analysis and bi-plots

The Spearman's rho correlation coefficient and bi-plots of nutrient concentrations and metrics were used to identify potential relationships between biological responses and nutrient variables. Correlation analyses identified the apparent linkage between biological condition and environmental variables. Bi-plots were examined to determine if the correlations reflected a "real" relationship.

Relationships of interest (those with high correlation coefficients) were examined using a locally weighted regression line (LOWESS or loess) to describe the trend of metric change along the environmental gradients. LOWESS technique (Cleveland 1979) is designed to address nonlinear relationships where linear methods do not perform well. LOWESS combines much of the simplicity of linear least squares regression with the flexibility of nonlinear regression. It achieves this by fitting simple models to localized subsets of the data to build up a function that describes the deterministic part of the variation in the data, point by point. LOWESS fits segments of the data to the model, essentially, at the central tendency of the data. This method does not require specification of a global function of any form to fit a model to the data but to simply fit segments of the data to the model. We used a bandwidth that considered 75% of the data for smoothing the slope at each data point. The LOWESS regression line can be used in combination with other indicators of nutrient thresholds of effect, primarily as a visual confirmation of changing biological measures at certain nutrient concentrations.

2.3 Change-point Analysis

The change-point is the point along an environmental gradient at which there is a high degree of change in the response variable. The data are divided into two groups, above and below a potential nutrient threshold, where each group is internally similar and the difference among groups is high. To determine the change-point, we use nonparametric deviance reduction (Qian et al. 2003, King and Richardson 2003) to identify thresholds in biological responses to nutrients. This technique is similar to regression tree models, which are used to generate predictive models of response variables for one or more predictors. Using this comparison, the change-point is the first split of a tree model with a single predictor variable (i.e., nutrient concentration). Output from change-point analyses will include the threshold as well as confidence intervals estimated from a bootstrapping re-sampling technique.

One caveat of the change-point analysis is that a change-point may be identified, and even determined to be statistically significant, when the change-point value is actually only an artifact of the analysis and not an indication of a change in system properties. The method always finds a changepoint, even in a dataset with a perfect straight line relationship between X and Y. It has been well established that nutrient concentrations limit algal growth as well as species composition. Therefore, it is reasonable to believe an ecological threshold does exist between certain periphyton metrics and nutrient concentrations. In our analyses, we evaluated this relationship by examining the LOWESS fit on biplots of periphyton metrics and nutrient concentrations. If the LOWESS fit did not show a visually recognizable change in the local regression, then the value identified through change-point analysis was disregarded.

2.4 Species Sensitivity Distributions

The Species Sensitivity Distribution (SSD) approach has been used to develop water quality criteria since the early eighties (Posthuma et al. 2002) using experimental data. Laboratory toxicity test detected responses (LC50) of a few species and these responses (sensitivities to toxicants) were then used to develop species sensitivity distributions. Water quality criteria derived using the SSD approach were based on dose-response relationships that examined the toxicity of the single constituent on a biological endpoint in a laboratory setting.

Recently, state and federal biomonitoring programs have accumulated ample species response data to allow testing of the SSD approach based on field observations (not just laboratory results). The field observed datasets have three notable advantages. 1) They are generally large dataset with multiple observations. 2) Hundreds of taxa were observed responding to various stressor gradients. 3) The criteria developed from this approach would be protective of individual taxa, not calculated metrics or indices.

The disadvantages of field observation are also evident. 1) Multiple stressors often exist concurrently and can confound response mechanisms. 2) Rare taxa (low capture probability, low abundance) may not be adequately incorporated into the analysis. 3) Systematic or random errors could be very large. While the SSD approach is a valuable way to develop nutrient thresholds and can provide an important line of evidence, we consider the use of the SSD approach to derive nutrient criteria from field data as an experimental approach and have to be cautious when applying the results.

The SSD approach to developing numeric stressor criteria involved examination of the Montana data to find responses of each individual taxon to nutrient variables. Response curves of macroinvertebrate taxa along nutrient gradients were described with Generalized Additive Models (GAM), which could be unimodal, decreasing, increasing, or U-shaped (concave-up). Both relative abundance and presence/absence of macroinvertebrate taxa were used as responses. To decrease effects of co-occurring stressors, sites were partitioned so that those with probable stress from non-nutrients were not included (e.g., sites with less than the 95th percentile of reference conductivity values).

After the relationships were determined, taxa tolerances to nutrients were identified and modeled through analysis of the taxa distributions and nutrient concentrations. Finally, based on the tolerance of each taxon, the cumulative distribution function was described for all observed taxa. This taxa tolerance distribution was examined to determine the nutrient levels at which a significant numbers of taxa (95%) were protected. The associated nutrient level was considered as a potential nutrient criterion. The SSD approach was used with nutrient - macroinvertebrate relationships, but because it is an exploratory approach, more details of the methods have been relegated to **Appendix D**.

2.5 Propensity scores

We used the propensity score approach to evaluate the plausibility that total phosphorus causes true biological effects. The propensity score approach accounts for background effects of multiple co-varying stressors before indicating if there are effects of total phosphorus that are independent of the other stressors. This approach was used almost entirely to infer the cause of biological impairment and prove that nutrient enrichment can impact the biological conditions (in general, not site-specifically).

The approach depends on identification of a number of streams with similar covariate distributions (other observed environmental factors), but which differ in nutrient concentrations. In the case of only a single factor (e.g., conductivity) covarying with nutrient concentrations, we could simply stratify the data set by this factor, splitting the data set into groups with similar values.

Propensity functions (Imai and Van Dyk 2004, Yuan 2010) summarize the contributions of all known covariates as a single parameter. A propensity function is defined as the conditional probability of a multivariate treatment (e.g., different nutrient concentrations), given values of known covariates. This conditional probability can be characterized by a single parameter, referred to here as the propensity score, which is the mean expected value of the treatment. For example, observed nutrient concentrations can be modeled as a function of covariate values using regression analysis, and the predicted mean nutrient concentration in each stream is the propensity score. Then, stratifying by propensity score effectively splits the data set into groups with similar covariate distributions. Once the data set is stratified, causal effects of nutrients can be more confidently estimated within each group because distributions of other covariates are similar (Yuan 2010). While effects thresholds can be identified, they would not be feasible to apply because of uncertainty in assigning new sites to propensity score classes.

The specific steps in the propensity score analysis include 1) identifying a suite of environmental variables that covary with nutrient concentrations, 2) using a generalized linear model (with appropriately transformed values) to summarize the covariates and predict nutrient concentrations, 3) stratifying the predicted TP (propensity scores) into four different classes, corresponding to perceived changes in TP expectations along the propensity score axis, and 4) characterizing relationships between biological responses and nutrient concentration in each of the strata.

It is expected that the limitation on periphyton can become irrelevant when nutrient concentrations reach certain high levels. In other words, the periphyton-nutrient relationship may be apparent when nutrients are limiting, but may not be apparent when nutrients are so plentiful that additional nutrients have no additional affect on periphyton. The propensity score analysis was only used with periphyton data because the effects of nutrients on periphyton are direct and our time for analyses was limited.

3 Results

3.1 Nutrient distribution descriptions

The 75th percentile of nutrient concentrations in reference sites provide a benchmark of concentrations that indicate nutrient conditions in 75 percent of those sites that are least impacted by human disturbance. The 75th – 95th percentiles of reference were derived from a set of 76 sites in all Level 3 ecoregions except the Wyoming Basin, which makes up a small proportion of the land in Montana. The ranges of 75th percentile values in the State were from 0.030 – 1.392 mg/L for total N and 0.002 – 0.149 mg/L for Total P (**Table 1**). When sub-setting the data by ecoregion or bioregion, the 75th percentile values for both Total N and Total P were highest in the Plains regions, where they were over 1 and 0.1 mg/L, respectively. The lowest values were observed in the mountainous regions, especially the Idaho Batholith and the Canadian Rockies. The Low Valley bioregion is a subset of lower elevation sites in the Middle Rockies. These sites showed somewhat higher concentrations of nutrients than other mountain sites. Other percentiles of the reference sites and of all sites show similar patterns among ecoregions and site classes.

Table 1. Summary of percentiles of TN and TP concentrations (mg/L) in all sites and only reference streams.

Data set:	All			Reference			
Percentile:	5th	10th	25th	75th	85th	90th	95th
Total Nitrogen							
Canadian Rockies	0.041	0.051	0.055	0.085	0.098	0.122	0.146
Idaho Batholith	0.055	0.055	0.055	0.030	0.030	0.030	0.030
Middle Rockies	0.055	0.055	0.090	0.175	0.281	0.330	0.779
Northern Rockies	0.025	0.055	0.055	0.114	0.126	0.193	0.232
Northwestern Glaciated Plains	0.112	0.178	0.331	1.115	1.335	1.465	1.865
Northwestern Great Plains	0.120	0.170	0.284	1.392	1.718	1.870	2.208
Wyoming Basin	0.319	0.345	0.410	NA	NA	NA	NA
Mountains	0.055	0.055	0.060	0.130	0.196	0.235	0.330
LowValley	0.055	0.055	0.125	0.223	0.389	0.518	0.646
Plains	0.144	0.217	0.383	1.320	1.712	1.815	2.302
Total Phosphorus							
Canadian Rockies	0.001	0.001	0.001	0.002	0.002	0.002	0.003
Idaho Batholith	0.001	0.001	0.004	0.002	0.002	0.002	0.002
Middle Rockies	0.001	0.003	0.010	0.010	0.026	0.041	0.081
Northern Rockies	0.001	0.002	0.004	0.010	0.011	0.012	0.013
Northwestern Glaciated Plains	0.003	0.008	0.019	0.110	0.132	0.164	0.315
Northwestern Great Plains	0.004	0.007	0.012	0.149	0.186	0.202	0.295
Wyoming Basin	0.016	0.022	0.030				
Mountains	0.001	0.001	0.004	0.010	0.010	0.013	0.026
LowValley	0.001	0.004	0.010	0.033	0.050	0.060	0.070
Plains	0.006	0.010	0.020	0.139	0.183	0.208	0.328

3.2 Benthic Macroinvertebrates

3.2.1 Sample collection methods

The predominant macroinvertebrate sampling method was the Kick method in both the Low Valley and the Mountain bioregions (**Table 2**). Targeted Riffle (TarRiff) methods focus on riffles within the reach, as do the Kick methods, and were used in several sites in these regions. Kick and Targeted Riffle methods were similar in benthic habitat targeted, responded to nutrient variables similarly, and had similar ranges along the nutrient gradient. Therefore, they were combined in analyses.

In the Mountains and Low Valley Regions, Jab and ReachWide (RW) samples were less common, mostly being used in low gradient, slow moving streams. Jab methods were almost exclusively used in high nutrient sites (TP > 0.028 mg/L). Because the reachwide methods were only used in certain site types, the reachwide samples were considered outliers in the metrics vs. TP bivariate plots and they were removed from analysis. Jab and ReachWide samples were analyzed together in the Mountains. In the Low Valleys, Kick and Targeted Riffle methods were used almost exclusively.

In the Plains, samples were grouped by methods as in the Mountains. Jab and Reachwide samples were almost as numerous as Kick and Targeted Riffle samples. The metric – nutrient bi-plots often showed separation of these method groups, with Jab and Reachwide samples more often associated with the higher end of the nutrient gradient.

Only a very limited number of Hess samples were collected and they were not included in subsequent analyses.

Table 2. Samples used in benthic macroinvertebrate analysis by ecoregion, site class and sampling protocol.

Ecoregion Name (#) or Site Class	Kick	TarRiff	Subtot	RW	Jab	Subtot	Hess
Canadian Rockies (41)	13	6	19	3	0	3	5
Idaho Batholith (16)	31	2	33	0	0	0	0
Middle Rockies (17)	354	36	390	10	6	16	15
Northern Rockies (15)	112	13	125	0	3	3	8
Northwestern Glaciated Plains (42)	78	16	94	21	41	62	7
Northwestern Great Plains (43)	137	14	151	37	90	127	11
Wyoming Basin (18)	5	0	5	0	2	2	0
LowValley	181	7	188	5	1	6	14
Mountains	360	42	402	9	8	17	19
Plains	189	25	214	57	133	190	13

3.2.2 Correlation analysis

An overview of Spearman rank correlations among selected variables across the whole state (regardless of region or sampling protocol) shows that some relationships are apparent before subdividing the data (**Table 3**). EPT taxa richness shows one of the most consistent associations with nutrient concentrations. It is also apparent from the high correlations with turbidity and conductivity that effects of non-nutrient variables may be as strong as nutrient effects. Additional correlation tables are presented in **Appendix A**.

Table 3. Correlation overview, with all samples across the state combined. Values with Spearman |r|>0.5 are shown in bold-type.

	TN	TP	TURB	pH	Conductivity
MtnIndex	**-0.621**	**-0.580**	**-0.702**	-0.351	**-0.678**
LowValIndex	-0.188	-0.217	-0.13	-0.132	-0.167
PlainsIndex	-0.317	-0.257	-0.411	-0.220	-0.364
O.E_p.half	-0.09	-0.145	-0.349	0.028	-0.031
EPTTax	**-0.627**	**-0.558**	**-0.734**	-0.387	**-0.748**
EphemTax	**-0.569**	**-0.523**	**-0.611**	-0.33	**-0.675**
PlecTax	**-0.634**	**-0.562**	**-0.795**	-0.378	**-0.706**
EPTPct	-0.479	-0.458	-0.349	-0.206	-0.485
EPTnoHBPct	**-0.539**	-0.475	**-0.539**	-0.304	**-0.589**
CrusMolPct	0.472	0.457	0.211	0.257	0.476
ScrapTax	**-0.553**	-0.482	**-0.627**	-0.350	**-0.655**
ShredderTax	**-0.520**	-0.387	**-0.745**	-0.372	**-0.643**
HBI	**0.646**	**0.557**	**0.725**	0.397	**0.708**

The subjective review of bi-plots with LOWESS regression lines revealed that 23 metrics and all three multimetric indices showed a response to nitrogen and phosphorus concentrations within the three macroinvertebrate ecoregions (**Table 4**). Of these metrics, 10 showed a consistent response in all bioregions.

EPT taxa richness declines with increasing TP concentrations in all three site classes (**Figure 1**) as did richness of Ephemeroptera, Plecoptera, and Trichoptera taxa considered separately, percent EPT individuals, and scraper richness. Percent Crustacea and Mollusca individuals, the Hilsenhoff Biotic Index (HBI), and percent burrower taxa increased with increasing nutrients in all three site classes. Other macroinvertebrate metrics respond to nutrients differently in different site classes. The nutrient-response relations are shown in **Appendix B**.

Table 4. Metrics and indices with significant responses to TN and TP in bioregions. (From analysis of scatter plots and Loess curves).

Metric	Mountain	LowValley	Plains
Mountain Index	-	-	
Low Valley Index		-	
Plains Index	-	-	
Mayfly, stonefly, caddisfly (EPT) taxa	-	-	-
Ephemeroptera taxa	-	-	-
Plecoptera taxa	-	-	-
Trichoptera taxa	-	-	-
% non-insect individuals	+		+
% mayfly, stonefly, caddisfly (EPT) individuals	-	-	-
% EPT individuals, excluding Hydropsychidae and Baetidae	-	-	-
% Chironomidae individuals	-		
% Orthocladiinae to all midge individuals			+
% Tanypodinae (midge) individuals	-		
% Crustacea and Mollusca individuals	+	+	+
Hilsenhoff Biotic Index (HBI)	+	+	+
Shredder taxa	-		-
Predator taxa	-	-	
Collector taxa			-
Filterer taxa			-
Scraper taxa	-	-	-
% predator individuals			-
% collector individuals	-		-
% filterer + collector individuals	+		
% filterer individuals	-		
% scraper individuals			-
% burrower taxa	+	+	+

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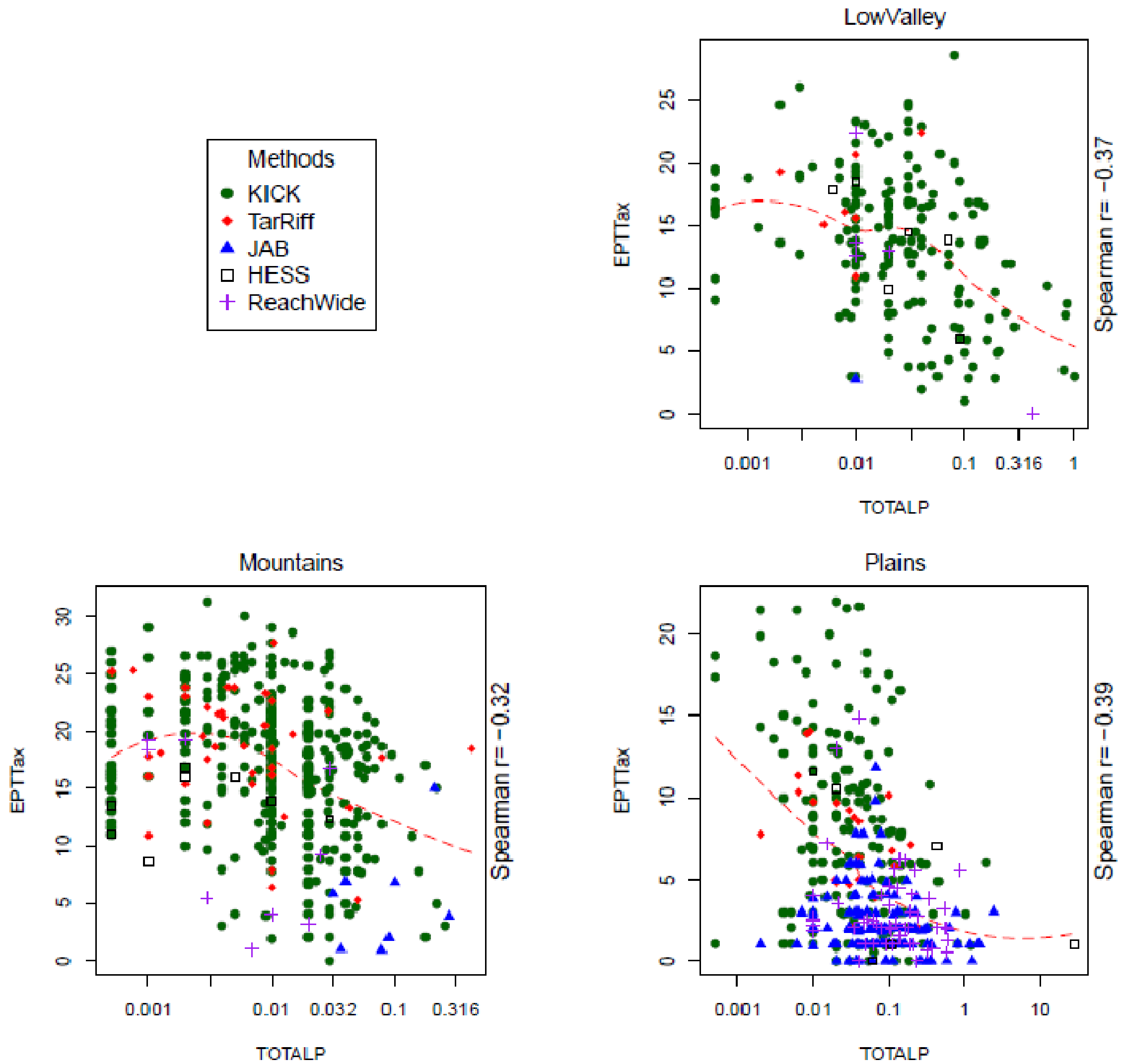

Figure 1. Example of bi-plots used to discern response patterns among nutrient concentrations and macroinvertebrate metrics. Data are separated by bioregion and marked by sampling protocol. The dashed line shows the LOWESS regression line.

3.2.3 Change-point Analysis

Change-point analysis resulted in identification of both significant and non-significant change-points. Only significant change-points should be considered. Results are tabulated and plotted for each ecoregion or bioregion, benthic method, and nutrient (**Appendix C**) and are summarized (**Table 4**) as the median of significant change-points. Some ecoregions do not appear in the summary for lack of sufficient sample size. **Figure 2** illustrates the change-point analysis for one nutrient – metric combination. In this example, the change point analysis generated a TP threshold around 0.048 mg/L TP with 90% confidence interval around 0.038 to 0.085 mg/L. The LOWESS regression line and its 90% confidence intervals also indicate a similar change point.

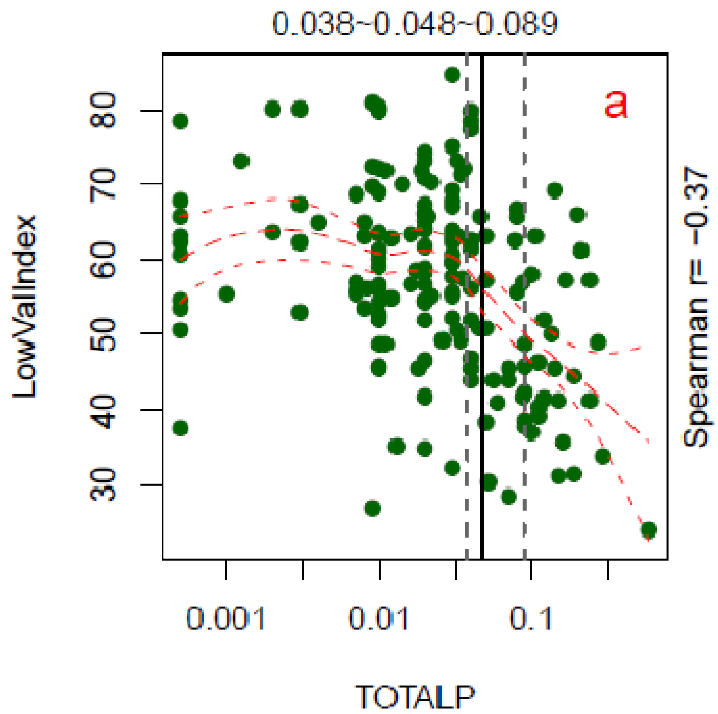

Figure 2. Example of a change point plot, with vertical lines representing the change point (solid) and 90% confidence intervals (dashed).

Table 4. Median of significant macroinvertebrate change-points by ecoregion or bioregion, benthic method, and nutrient.

Region	methods	TN	TP
Middle Rockies	Kick_Riff	0.317	0.033
Northern Rockies	Kick_Riff	0.1385	0.008
Northwestern Glaciated Plains	JAB_Reach	1.2865	0.1055
Northwestern Glaciated Plains	Kick_Riff	0.466	0.0235
Northwestern Great Plains	JAB_Reach	1.116	0.058
Northwestern Great Plains	Kick_Riff	0.619	0.022
Low Valley	KickOnly	0.379	0.051
Mountains	Kick_Riff	0.202	0.015
Plains	JAB_Reach	1.320	0.110
Plains	Kick_Riff	0.619	0.030

TN and TP change-points show patterns that similar to those observed in reference site distributions -- mountainous regions have lower change-point nutrient values and plains regions show the highest. In the Northern Rockies ecoregion and the Mountains bioregion, macroinvertebrate change-points were generally observed at concentrations of 0.19 – 0.28 mg/L TN and 0.011 – 0.017 mg/L TP. The Middle Rockies and Low Valleys showed change-points at intermediate concentrations of 0.36 – 0.48 mg/L TN and 0.040 – 0.060 mg/L TP.

In the Plains ecoregions and bioregion, the change-point analysis was sensitive to macroinvertebrate sampling method. Depending on the ecoregion and sampling method, change-points for TN concentrations varied from 0.5 to 1.47 mg/L and for TP concentrations varied from 0.028 to 0.193 mg/L. The higher nutrient values were always associated with Jab and ReachWide macroinvertebrate sampling methods. We noted earlier that Jab and ReachWide methods were generally used in sites with slower currents and higher nutrient concentrations. It is difficult to discern from these analyses whether these methods were used in truly different site types which warrant different nutrient criteria or the analytical results are an artifact of site conditions associated with sampling methods, but not representative of different nutrient expectations or potentials. The change-points associated with Jab and ReachWide methods are more closely aligned with the reference 75th percentiles for these regions.

3.2.4 Species Sensitivity Distributions

The most robust approach for identifying taxa tolerance values was the 95% cumulative probability of the modeled response curve. Tolerance values that were protective of 95% of the taxa (**Table 5**) were comparable to values derived with other approaches. The potential criteria for TN and TP are lowest in the Mountainous regions and highest in the Plains regions. Especially high thresholds were identified in the subset of data collected using Jab and Reachwide macroinvertebrate methods.

Table 5. Numeric TN and TP criteria derived from the taxon sensitivity distribution approach using partitioned data.

Groups	Ref	Sensitive
	Total Nitrogen (mg/L)	
1 LowValley KICK	1.159	0.835
2 Mountains KICK	0.446	0.377
3 Plains JAB	3.27	3.015
4 Plains KICK	0.937	0.828
	Total Phosphorus (mg/L)	
5 LowValley KICK	0.059	0.045
6 Mountains KICK	0.022	0.016
7 Plains JAB	0.455	0.462
8 Plains KICK	0.077	0.063

Ref - Taxa occurred in reference sites
Sensitive - Sensitive taxa occurred in at least 30 sites

3.3 Periphyton

3.3.1 Correlation Analysis

A non-parametric Spearman rank correlation analysis was used to identify the periphyton metrics that were related to nutrient concentrations and to the other major covariates in the entire State. Twenty-five (25) of the 90 periphyton metrics were correlated to either TN or TP with Spearman rho values >0.50 or <-0.50, and p<0.01. (**Table 6**). Other metrics were significantly correlated, but not as strongly (**Appendix E**, includes correlations by ecoregion). Many of the metrics that were related to nutrients were also significantly related to the co-varying variables, especially conductivity, alkalinity, chloride, and hardness.

Table 6. Spearman rank correlation coefficients between periphyton metrics, nutrient concentrations, and other major covariates. See **Table 7** for descriptions of the metrics.

Metrics	TN	TP	COND	Temp	Alk	Chlor	Hard	TSS
pi_Diat_CA_2	**-0.51**	-0.43	**-0.70**	-0.43	**-0.73**	-0.48	**-0.65**	-0.43
pi_Diat_CL_2	-0.44	**-0.52**	**-0.51**	-0.34	**-0.55**	**-0.56**	-0.49	-0.49
pi_Diat_Cond_1	**0.51**	0.44	**0.59**	0.37	**0.61**	**0.59**	**0.50**	0.48
pi_Diat_Cond_2	**-0.50**	-0.41	**-0.59**	-0.33	**-0.62**	-0.38	**-0.57**	-0.35
pi_Diatas_TN_2	-0.31	**-0.52**	-0.39	-0.25	-0.42	-0.37	-0.37	-0.39
pi_Diatas_TP_1	**0.50**	**0.58**	**0.55**	0.30	**0.54**	**0.51**	0.44	0.43
pi_Diatas_TP_2	-0.38	**-0.57**	-0.37	-0.32	-0.38	-0.35	-0.32	-0.35
pi_Motility_1	0.38	**0.51**	**0.50**	0.26	**0.53**	0.49	0.42	0.44
wa_OxyTol	0.33	**0.54**	0.37	0.19	0.40	0.38	0.35	0.35
wa_Poll_Class	-0.42	**-0.51**	-0.41	-0.24	-0.43	-0.47	-0.34	-0.44
wa_Salinity	**0.61**	**0.51**	**0.75**	0.46	**0.75**	**0.63**	**0.66**	0.49
pi_Ptpv_TN_all_Lo	-0.36	**-0.54**	**-0.51**	-0.28	**-0.53**	-0.45	-0.48	-0.43
pi_Ptpv_TN_WM_Lo	-0.39	**-0.55**	-0.45	-0.34	-0.48	-0.40	-0.41	-0.41
pi_Ptpv_TP_all_Lo	-0.40	**-0.59**	-0.42	-0.32	-0.43	-0.39	-0.35	-0.38
pi_Ptpv_TP_WM_Lo	-0.42	**-0.56**	-0.40	-0.33	-0.41	-0.39	-0.34	-0.39
wa_AVGTSIC	0.49	**0.51**	0.48	0.30	**0.50**	0.29	0.39	0.29
wa_MAIATSIC	0.49	**0.51**	0.48	0.30	**0.50**	0.29	0.39	0.29
wa_OptCat_DisTotMMI	**0.54**	**0.61**	**0.55**	0.42	**0.54**	0.49	0.42	0.45
wa_OptCat_L1DisTot	**0.58**	**0.55**	**0.64**	0.47	**0.62**	0.49	**0.50**	0.47
wa_OptCat_L1Ptl	**0.54**	**0.63**	**0.54**	0.39	**0.55**	**0.53**	0.44	0.45
wa_OptCat_LCond	**0.54**	**0.53**	**0.65**	0.45	**0.65**	0.49	**0.54**	0.45
wa_OptCat_LNtl	**0.58**	**0.60**	**0.62**	0.45	**0.61**	**0.55**	0.49	0.48
wa_OptCat_NutMMI	**0.55**	**0.63**	**0.57**	0.41	**0.58**	**0.54**	0.46	0.47
wa_OptCat_PctFN	0.45	**0.57**	0.47	0.28	0.49	**0.54**	0.38	0.43
wa_OptCat_XEMBED	**0.51**	**0.56**	**0.54**	0.39	**0.54**	**0.54**	0.43	0.45

Table 7. Periphyton metric descriptions, for the metrics most highly correlated with nutrients or with significant changepoints.

Metrics	Source	Description
pi_Diat_CA_2	Porter	% Calcium sensitive diatoms
pi_Diat_CL_2	Porter	% Chloride sensitive diatoms 2
pi_Diat_Cond_1	Porter	% high conductivity requirement diatoms
pi_Diat_Cond_2	Porter	% conductivity sensitive diatoms
pi_Diatas_TN_2	Porter	% TN sensitive diatoms
pi_Diatas_TP_1	Porter	% high TP requirement diatoms
pi_Diatas_TP_2	Porter	% TP sensitive diatoms
pi_Motility_1	Porter	% highly Motile
wa_OxyTol	Porter	weighted average, Oxygen Tolerant
wa_Poll_Class	Porter	weighted average, Pollution Tolerant Class
wa_Salinity	Porter	weighted average, Salinity
pi_Ptpv_TN_all_Lo	Potapova	% low TN all regions
pi_Ptpv_TN_WM_Lo	Potapova	% low TN Western Mountain region
pi_Ptpv_TP_all_Lo	Potapova	%, low TP all regions
pi_Ptpv_TP_WM_Lo	Potapova	% low TP, Western Mountains
wa_AVGTSIC	Stevenson	trophic state index
wa_MAIATSIC	Stevenson	Trophic state index based on Middle Atlantic Highland region periphyton data
wa_OptCat_DisTotMMI	Stevenson (WEMAP)	weighted average, mult-metric index
wa_OptCat_L1DisTot	Stevenson (WEMAP)	weighted average, disturbance index
wa_OptCat_L1Ptl	Stevenson (WEMAP)	Western EMAP Weighted average TP score
wa_OptCat_LCond	Stevenson (WEMAP)	weighted average Conductivity score
wa_OptCat_LNtl	Stevenson (WEMAP)	Western EMAP Weighted average TN score
wa_OptCat_NutMMI	Stevenson (WEMAP)	Western EMAP multi-variate/metric index of nutrients
wa_OptCat_PctFN	Stevenson (WEMAP)	weighted average % fine score
wa_OptCat_XEMBED	Stevenson (WEMAP)	weighted average embeddedness score
pi_IncMtnNut	Teply and Bahls 2005	% Increasers, Mountains Nutrients
pi_Ptpv_TP_CWP_Lo	Potapova	% TP sensitive in Central and Western Plains
pi_Trophic_56	Porter	% Trophic = 5 or 6
wa_Poll_Tol	Porter	weighted average, Pollution Tolerance index
x_Kelly_TDI	Kelly	Kelly's Index. TDI = (WMS*25)-25. 0-100 (modified for if WMS =0 so TDI = 0). WMS = sum(abundance*S*v) / sum(abundance*v)
pi_Ptpv_TN_CWP_Lo	Potapova	percent individuals, TN in Central and Western Plains

pi = percent individuals, wa = weighted average.

3.3.2 Change-point Analysis

Change-point analysis resulted in identification of both significant and non-significant change-points, depending on the metric, nutrient, and ecoregion. Only significant change-points (p<0.05) were considered. Results are tabulated for each ecoregion or bioregion and nutrient (**Appendix E**) and are summarized (**Table 8**).

Table 8. Significant change-points by periphyton metric, ecoregion, and nutrient.

	Ecoregion	15	16	17	42	43
TN	median CP:		0.285	0.515	0.28	0.341
pi_Ptpv_TN_all_Lo					0.28	0.341
pi_Ptpv_TN_CWP_Lo			0.285	0.515	0.965	0.692
pi_Ptpv_TN_WM_Lo					0.172	0.299
TP	median CP:	0.017	0.003	0.021	0.012	0.008
pi_Diatas_TP_1		0.028	0.007	0.038	0.023	0.036
pi_IncMtnNut		0.029	0.003	0.012	0.009	
pi_Ptpv_TP_all_Lo		0.013	0.003	0.017	0.007	0.007
pi_Ptpv_TP_CWP_Lo		0.007	0.003	0.005	0.007	0.008
pi_Ptpv_TP_WM_Lo		0.004	0.003	0.016	0.017	0.008
pi_Trophic_56		0.029	0.003	0.027	0.012	0.008
wa_MAIATSIC		0.028	0.003	0.025	0.007	0.007
wa_OptCat_DisTotMMI		0.017	0.014	0.021	0.02	0.011
wa_OptCat_NutMMI		0.017	0.005	0.021	0.017	0.011
wa_Poll_Tol				0.029	0.023	0.029
x_Kelly_TDI				0.021	0.007	0.007

The change-point analysis was also conducted using pooled data from all ecoregions. **Figures 3** and **4** illustrate the change-point analysis for selected metrics. For TN, the change point analysis generated thresholds ranging from 0.451 – 0.512 mg/L (median 0.497 mg/L) TN for this set of metrics. For TP, the change point analysis generated thresholds ranging from 0.013 – 0.034 mg/L (median 0.025 mg/L) TP for this set of metrics. The LOWESS regression lines are relatively steep at the change-points, indicating agreement with the identified change-point. Results from these statewide analyses generally agree with the highest median values identified in the ecoregion-specific analyses.

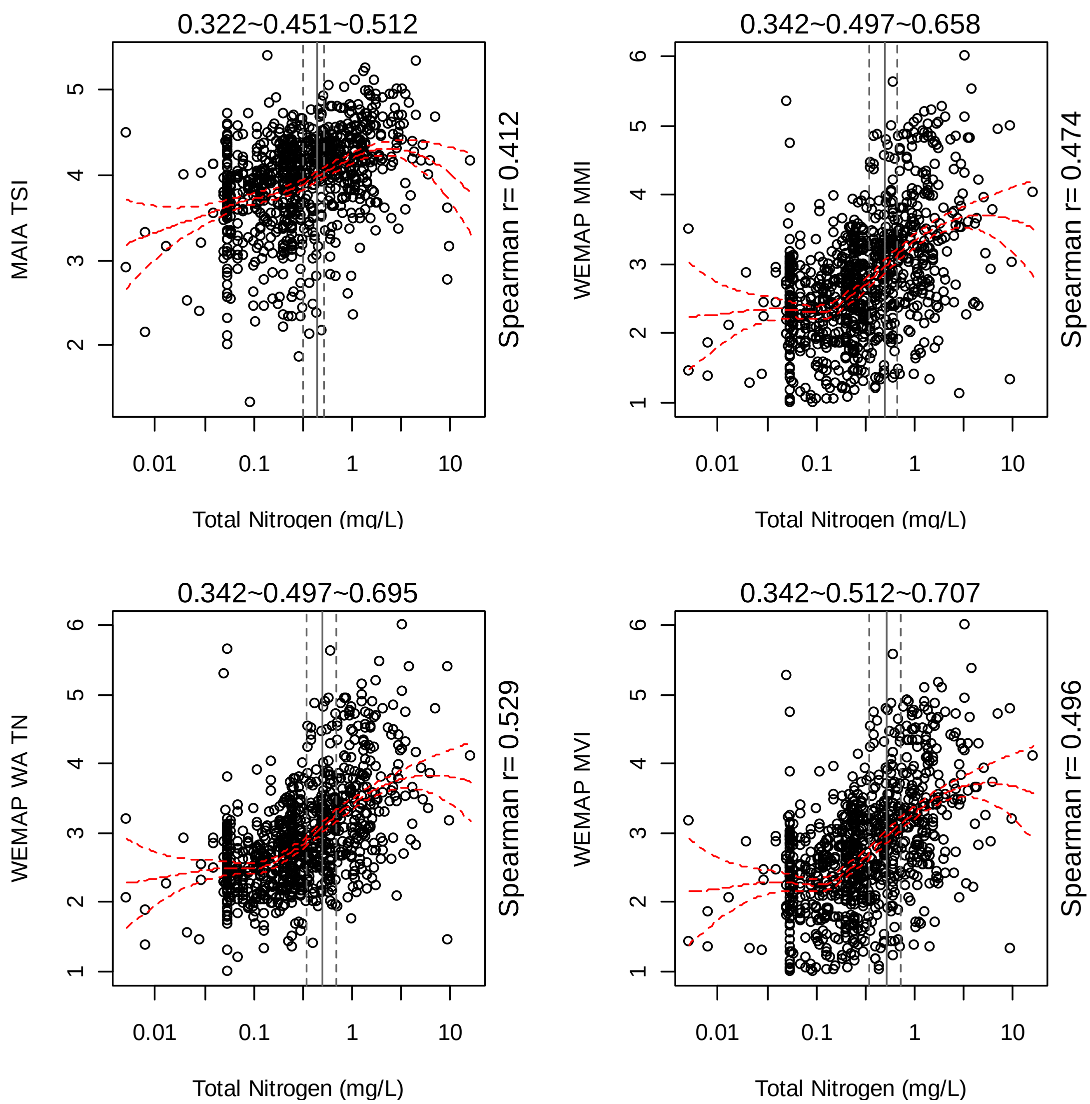

Figure 3. Responses of TN sensitive algal metrics to increased TN concentrations in the State of Montana. The vertical lines are the change point and their 90% confidence limits. The smooth curves are the LOWESS fit and their 90% confidence limits. Spearman correlation coefficients are also reported. The response variables are MAIA TSI (wa_MAIATSIC), WEMAP MMI (wa_OptCat_NutMMI), WEMAP WA TN (wa_OptCat_LNtl), WEMAP MVI (wa_OptCat_NutMMI).

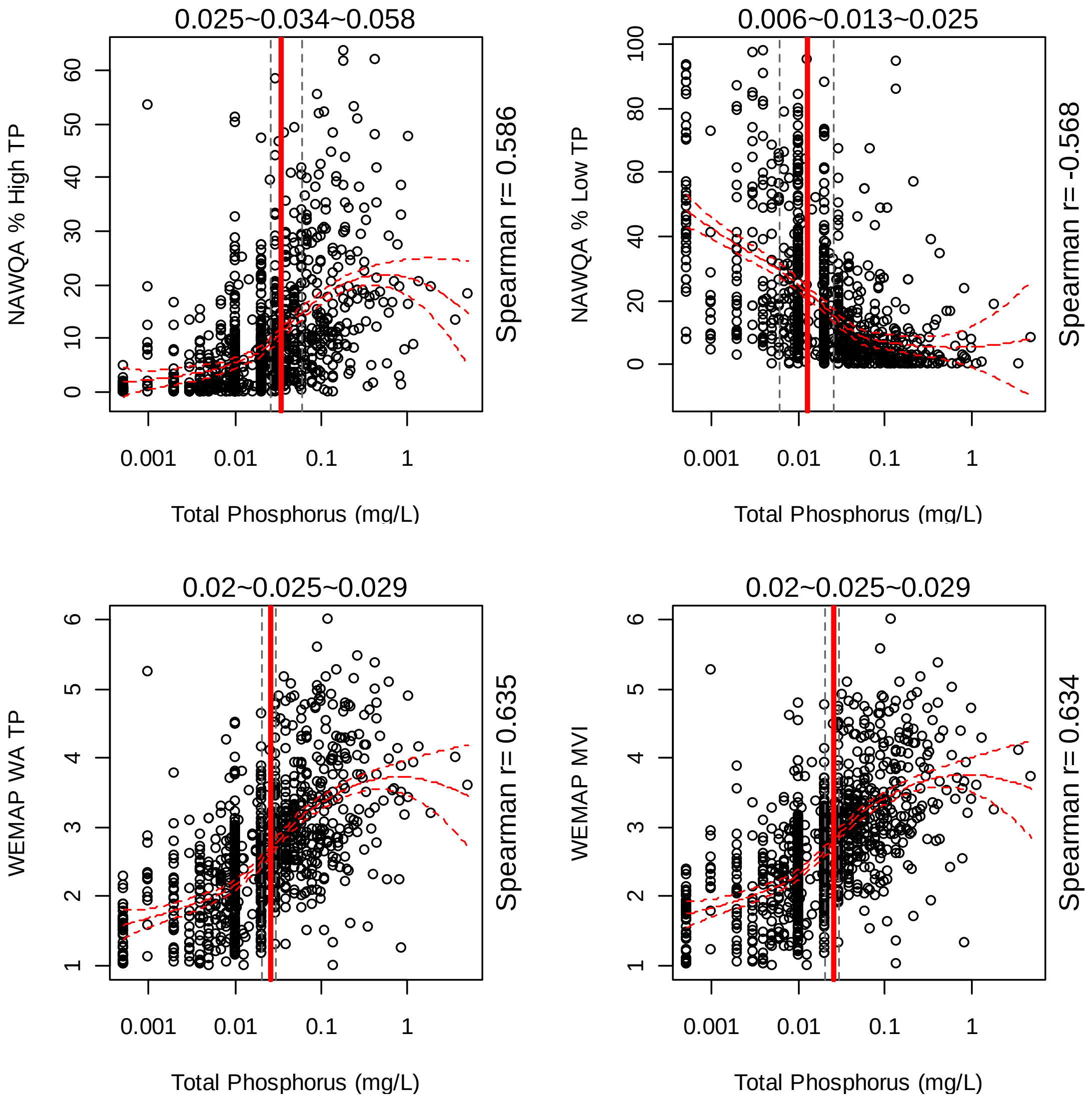

Figure 4. Responses of TP sensitive algal metrics to increased TP concentrations in the State of Montana. The vertical lines are the change points and their 90% confidence limits. The smooth curves are the LOWESS fit and their 90% confidence limits. Spearman correlation coefficients are also reported. The response variables are NAWQA % high TP (pi_Diatas_TP_1), NAWQA % low TP (pi_Diatas_TP_2), WEMAP WA TP (wa_OptCat_), WEMAP MVI (wa_OptCat_NutMMI).

3.2.3 Propensity Score Analysis

The environmental variables included in the propensity score analysis included conductivity, water temperature, alkalinity, chloride, hardness, and total suspended solids because they are also potentially associated with biological degradation in the State. Because total nitrogen is highly correlated with total phosphorus (Spearman rho ~ 0.80), effects observed on phosphorus after accounting for nitrogen are expected to be similar to effects of nitrogen after accounting for phosphorus. Therefore only effects with total phosphorus were examined and similar effects of nitrogen were then implied. These analyses were conducted with all data statewide, not by ecoregion.

Using the six variables and a generalized linear model on log transformed data (except temperature), the predicted TP (propensity scores) were stratified into four different classes, corresponding to perceived changes in TP expectations along the propensity score axis (**Figure 5**). Correlations of the variables in the model with the propensity scores (**Table 9**) indicate that Class 1 (left of the first vertical line in **Figure 5**) has the lowest TSS and TKN, as well as lower conductivity, alkalinity, temperature, chloride, and hardness and somewhat higher chlorophyll *a* and dissolved oxygen. Sites with greater degrees of stress are in Class 4 (furthest right in the figure). Correlations of TP with covariates were greatly reduced within the classes in comparison to correlations in all sites (pooled classes). Correlations of TP with TN and TKN remained relatively high in the individual classes.

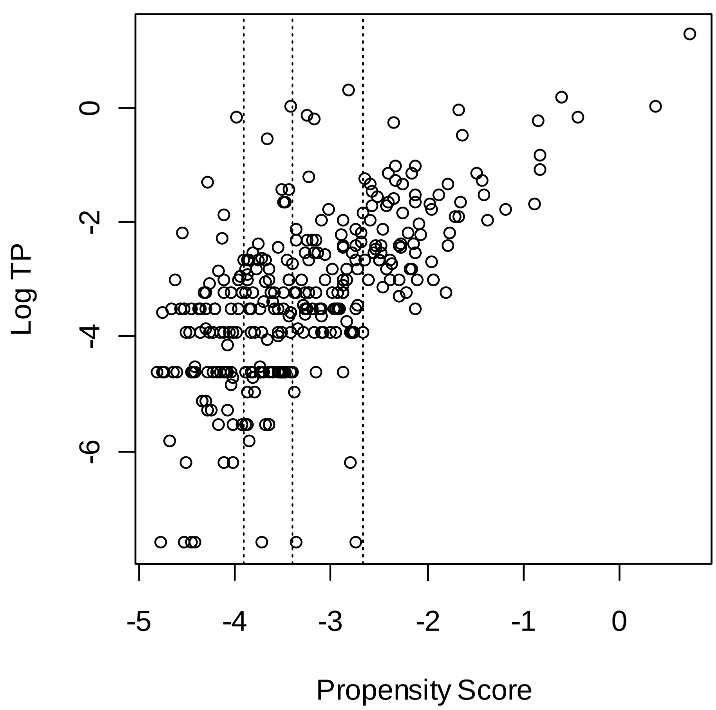

Figure 5. Scatterplot of propensity scores versus log TP. The samples were stratified into four classes, delineated by the vertical dashed lines.

Table 9. Correlations (Spearman rho) of Total Phosphorus with environmental covariates in all groups and in four propensity classes.

	All samples	Class 1	Class 2	Class 3	Class 4
Conductivity	0.306	0.087	-0.151	0.011	-0.105
Temperature	0.360	0.197	-0.261	0.093	0.048
Alkalinity	0.348	0.090	-0.207	0.051	-0.083
Chloride	0.274	0.229	-0.078	-0.069	-0.147
Hardness	0.256	0.087	-0.282	0.007	-0.167
TSS	0.611	-0.046	0.205	-0.054	0.436
TKN	0.653	0.424	0.316	0.356	0.597
Chlorophyll a	-0.121	-0.229	0.110	-0.026	-0.081
Dissolved oxygen	-0.162	-0.078	-0.066	-0.113	0.004
pH	0.168	0.098	-0.159	-0.241	-0.001
TN	0.617	0.402	0.317	0.411	0.560

Periphyton responses to TP were examined using the WEMAP MMI, because it showed a robust response in other analyses. The MMI increases with increasing nutrient stress. The relationship was characterized through TP-MMI bi-plots within propensity score classes, with the LOWESS regression line and change-point analysis superimposed on the graph. As expected, periphyton responses to TP were evident in the classes with lower stressor intensities, where a change-point with relatively narrow confidence intervals could be identified in association with a change in the LOWESS curve (**Figure 6**).

In Class 4, where virtually all of the TP values were greater than 0.03 mg/L, there was no obvious trend or change-point in periphyton MMI values along the TP gradient. These results suggest that TP has an effect on periphyton when TP and background stressors are less than 0.03 mg/L. At higher values, additional TP does not change the periphyton characteristics. The change-points identified in Classes 1 – 3 suggest that effect thresholds may occur when TP is between 0.013 and 0.028 mg/L, depending on background expectations that may be accountable through site classification. When ecoregions were associated with propensity scores, there was no discernable pattern to suggest that propensity score classes and ecoregions were aligned. If they had been aligned, then ecoregions would be accounting for the same factors considered in developing the propensity scores. As it is, they account for different factors, but this does not imply that one is more accurate than the other.

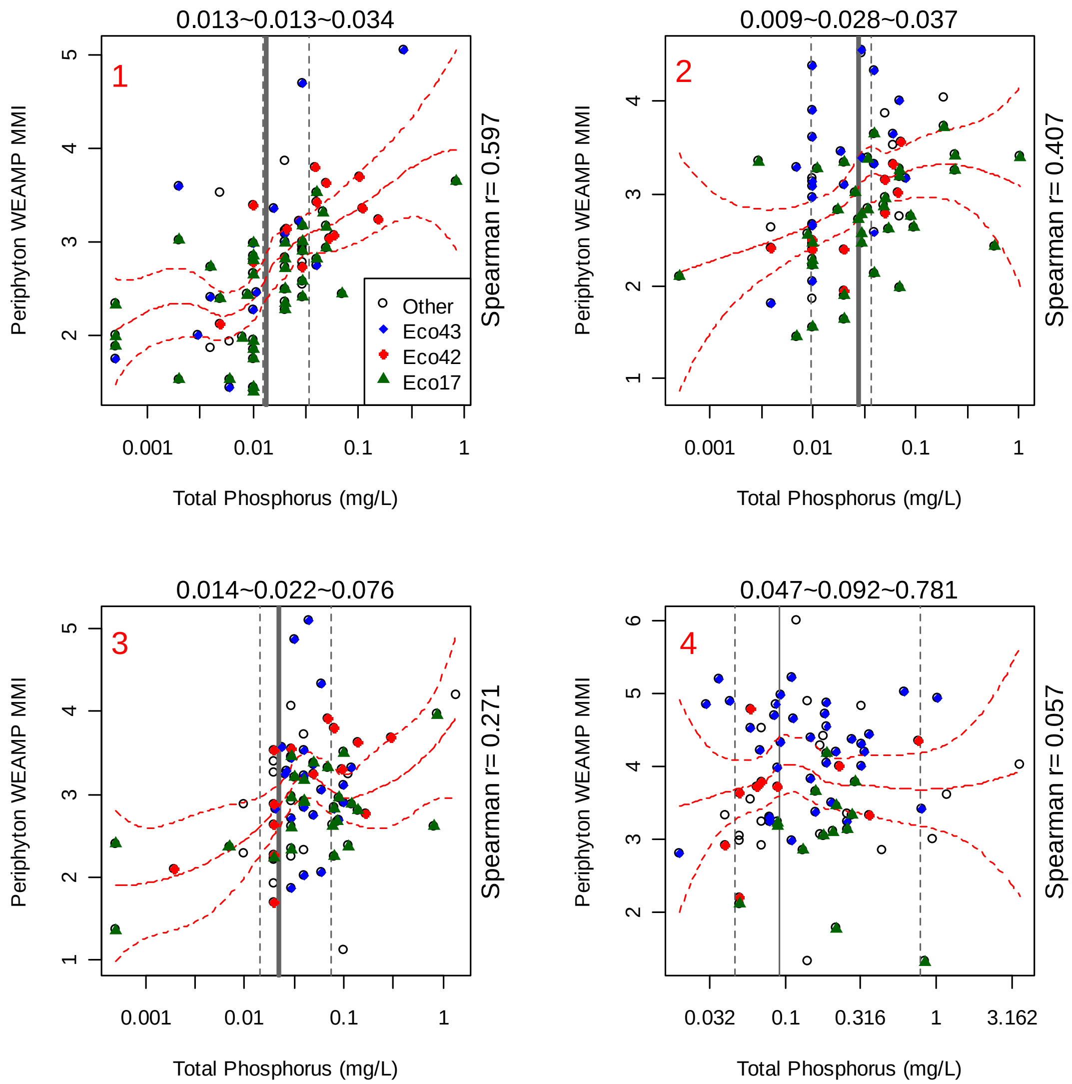

Figure 6. Response of WEMAP MMI to TP concentrations in each of the four propensity classes. The vertical lines are the change points and their 90% confidence limits.

4 Discussion

Multiple approaches were taken to describe nutrient conditions in Montana streams, to relate those conditions to biological conditions, and to suggest possible thresholds of nutrient concentrations that might guide selection of nutrient criteria. Total Nitrogen (TN) and Total Phosphorus (TP) were related to biological conditions using several approaches. We presented the most promising approaches, emphasizing Change-point Analysis as the primary technique, which is supported using Species Sensitivity Distributions for macroinverebrates and Propensity Score Analysis for periphyton. A fourth technique, Conditional Probability Analysis, was considered but then abandoned because the required biological thresholds of impairment were under review at the time of the analysis and setting such thresholds based on an arbitrary percentile of metric values was unsatisfactory. The combination of results from the multiple techniques allows reviewers to weight such evidence in selecting final criteria levels or in directing further research.

TN and TP were lower in reference sites relative to non-reference sites in most ecoregions, though in the Plains ecoregions, nutrients in reference sites were variable and not especially low. The 75th percentiles of reference site values were identified in ecoregions and bioregions as potential nutrient thresholds. These values are descriptive of the background conditions of the streams, but are not explicitly associated with biological conditions, and therefore do not demonstrate direct protection of aquatic life.

Results of TP and TN threshold identification analysis by ecoregion and bioregion of Montana are compiled in **Tables 10** and **11**. The results are further summarized as the medians of analyses by regions in **Table 12**. For TN in the mountainous regions, potential thresholds range from 0.030 to 0.515 mg/L TN. The lowest values were derived from reference distributions and the highest values were derived from change-point analysis with periphyton in the Middle Rockies. If the Middle Rockies are accepted as an anomaly due to low valley sites, the median TN criterion in the mountains is 0.139 mg/L. In the Middle Rockies and Low Valleys bioregion, slightly higher TN thresholds were derived, with median values of 0.401 and 0.660 mg/L, respectively. In the Plains regions, the range of potential thresholds was broad (0.28 – 3.27 mg/L TN), with the lowest values associated with the change-point analysis using periphyton and the highest values associated SSD in jab samples. The median value among the suggested thresholds was 1.115 mg/L TN. The distinction between sites sampled with jab versus kick methods should be further explored. We suspect that these are different site types, which might warrant lower criteria in sites with stream gradients steep enough to allow kick sampling.

For TP in the mountainous regions, potential thresholds range from 0.002 to 0.033 mg/L TP. The lowest values were derived from reference distributions and change-point analysis with periphyton in the Idaho Batholith. The highest values were derived from changepoint analyses in the Middle Rockies. If the Middle Rockies are accepted as an anomaly due to low valley sites, the median TP criterion in the mountains is 0.010 mg/L. In the Middle Rockies and Low Valleys bioregion, slightly higher TP criteria were derived, with median values of 0.021 and 0.048 mg/L, respectively. In the Plains regions, the range of potential thresholds was broad (0.008 – 0.462 mg/L TP), with the lowest values associated with the change-point analysis using periphyton and the highest values associated SSD in jab samples. The median value among the suggested thresholds was 0.077 mg/L TP. Differences in expectations relative to stream gradient should be further explored.

Table 10. Potential criteria for total nitrogen.

TN (mg/L)	Analysis	Bioregion	Ecoregion	Assemblage
0.202	Change-point Analysis	Mountains	(bioregion-wide)	Macroinvertebrates
0.446	SSD- Reference	Mountains	(bioregion-wide)	Macroinvertebrates
0.377	SSD- Sensitive	Mountains	(bioregion-wide)	Macroinvertebrates
0.130	75th %ile of reference	Mountains	(bioregion-wide)	NA
0.085	75th %ile of reference	Mountains	Canadian Rockies	NA
0.030	75th %ile of reference	Mountains	Idaho Batholith	NA
0.285	Change-point Analysis	Mountains	Idaho Batholith	Periphyton
0.139	Change-point Analysis	Mountains	Northern Rockies	Macroinvertebrates
0.114	75th %ile of reference	Mountains	Northern Rockies	NA
0.317	Change-point Analysis	Mtns/LV	Middle Rockies	Macroinvertebrates
0.317	Change-point Analysis	Mtns/LV	Middle Rockies	Macroinvertebrates
0.175	75th %ile of reference	Mtns/LV	Middle Rockies	NA
0.175	75th %ile of reference	Mtns/LV	Middle Rockies	NA
0.515	Change-point Analysis	Mtns/LV	Middle Rockies	Periphyton
0.515	Change-point Analysis	Mtns/LV	Middle Rockies	Periphyton
0.484	Change-point Analysis	Low Valley	(bioregion-wide)	Macroinvertebrates
1.159	SSD- Reference	Low Valley	(bioregion-wide)	Macroinvertebrates
0.835	SSD- Sensitive	Low Valley	(bioregion-wide)	Macroinvertebrates
0.223	75th %ile of reference	Low Valley	(bioregion-wide)	NA
1.320	Change-point Analysis	Plains	(bioregion-wide)	Macroinvert-Jab
3.270	SSD- Reference	Plains	(bioregion-wide)	Macroinvert-Jab
3.015	SSD- Sensitive	Plains	(bioregion-wide)	Macroinvert-Jab
0.619	Change-point Analysis	Plains	(bioregion-wide)	Macroinvert-Kick
0.937	SSD- Reference	Plains	(bioregion-wide)	Macroinvert-Kick
0.828	SSD- Sensitive	Plains	(bioregion-wide)	Macroinvert-Kick
1.320	75th %ile of reference	Plains	(bioregion-wide)	NA
1.287	Change-point Analysis	Plains	NW Glaciated Plains	Macroinvert-Jab
0.466	Change-point Analysis	Plains	NW Glaciated Plains	Macroinvert-Kick
1.115	75th %ile of reference	Plains	NW Glaciated Plains	NA
0.280	Change-point Analysis	Plains	NW Glaciated Plains	Periphyton
0.341	Change-point Analysis	Plains	NW Glaciated Plains	Periphyton
1.116	Change-point Analysis	Plains	NW Great Plains	Macroinvert-Jab
0.619	Change-point Analysis	Plains	NW Great Plains	Macroinvert-Kick
1.392	75th %ile of reference	Plains	NW Great Plains	NA

Table 11. Potential criteria for total phosphorus.

TP (mg/L)	Analysis	Bioregion	Ecoregion	Assemblage
0.01	75th %ile of reference	Mountains	(bioregion-wide)	NA
0.015	Change-point Analysis	Mountains	(bioregion-wide)	Macroinvertebrates
0.022	SSD- Reference	Mountains	(bioregion-wide)	Macroinvertebrates
0.016	SSD- Sensitive	Mountains	(bioregion-wide)	Macroinvertebrates
0.002	75th %ile of reference	Mountains	Canadian Rockies	NA
0.003	Change-point Analysis	Mountains	Idaho Batholith	Periphyton
0.002	75th %ile of reference	Mountains	Idaho Batholith	NA
0.01	75th %ile of reference	Mountains	Northern Rockies	NA
0.008	Change-point Analysis	Mountains	Northern Rockies	Macroinvertebrates
0.017	Change-point Analysis	Mountains	Northern Rockies	Periphyton
0.01	75th %ile of reference	Mtns/LV	Middle Rockies	NA
0.01	75th %ile of reference	Mtns/LV	Middle Rockies	NA
0.033	Change-point Analysis	Mtns/LV	Middle Rockies	Macroinvertebrates
0.033	Change-point Analysis	Mtns/LV	Middle Rockies	Macroinvertebrates
0.021	Change-point Analysis	Mtns/LV	Middle Rockies	Periphyton
0.021	Change-point Analysis	Mtns/LV	Middle Rockies	Periphyton
0.033	75th %ile of reference	Low Valley	(bioregion-wide)	NA
0.051	Change-point Analysis	Low Valley	(bioregion-wide)	Macroinvertebrates
0.059	SSD- Reference	Low Valley	(bioregion-wide)	Macroinvertebrates
0.045	SSD- Sensitive	Low Valley	(bioregion-wide)	Macroinvertebrates
0.139	75th %ile of reference	Plains	(bioregion-wide)	Macroinvertebrates
0.110	Change-point Analysis	Plains	(bioregion-wide)	Macroinvert-Jab
0.030	Change-point Analysis	Plains	(bioregion-wide)	Macroinvert-Kick
0.455	SSD- Reference	Plains	(bioregion-wide)	Macroinvert-Jab
0.077	SSD- Reference	Plains	(bioregion-wide)	Macroinvert-Kick
0.462	SSD- Sensitive	Plains	(bioregion-wide)	Macroinvert-Jab
0.063	SSD- Sensitive	Plains	(bioregion-wide)	Macroinvert-Kick
0.106	Change-point Analysis	Plains	Glaciated – Jab/RW	Macroinvert-Jab
0.024	Change-point Analysis	Plains	Glaciated – Kick/Riff	Macroinvert-Kick
0.058	Change-point Analysis	Plains	Great – Jab/RW	Macroinvert-Jab
0.022	Change-point Analysis	Plains	Great – Kick/Riff	Macroinvert-Kick
0.110	75th %ile of reference	Plains	NW Glaciated Plains	Macroinvertebrates
0.012	Change-point Analysis	Plains	NW Glaciated Plains	Periphyton
0.149	75th %ile of reference	Plains	NW Great Plains	Macroinvertebrates
0.008	Change-point Analysis	Plains	NW Great Plains	Periphyton

Table 12. Median and quartile ranges for potential nutrient criteria in Montana regions.

Total Nitrogen			Total Phosphorus		
25th %ile	median	75th %ile	25th %ile	median	75th %ile
Mountains - Idaho Batholith, Northern Rockies, Canadian Rockies					
0.114	0.139	0.285	0.004	0.010	0.016
Middle Rockies (including Low Valleys)					
0.247	0.401	0.515	0.013	0.021	0.030
Low Valley (subset of Middle Rockies)					
0.419	0.660	0.916	0.042	0.048	0.053
Plains					
0.619	1.115	1.32	0.027	0.077	0.125

In the change-point analysis, the algorithm will find a changepoint regardless of whether there is one or not. This weakness of the analysis was addressed by discounting change-points that did not have LOWESS regression lines that confirmed results. While the judgment of confirmation was visual and subjective, reliance on corroborated results from multiple metrics and alternative analyses probably decreased the chances for error.

A second criticism of change-point analysis is that a numerical change-point may or may not have anything to do with a biologically significant change, or an effect on designated uses. The benthic multimetric index has been associated with biological thresholds, which could be checked against the change-points to determine if the biological threshold coincides with the nutrient change-point. The MMI was not calibrated specifically to any one stressor such as nutrients, so the coincidence of thresholds might not be expected. Thresholds that indicate biological significance for other metrics were not identified.

The species sensitivity distribution technique has not been adequately refined or tested for this application. Potential threshold values from the SSD analysis were higher than most other approaches, especially for jab samples in the plains. Because we focus on central tendencies of all the analyses, these extreme values are generally discounted as potential criteria.

The propensity score analysis results revealed that periphyton indices could be used as indicators of nutrient enrichment and therefore could be valid tools for nutrient criteria development. In addition, the propensity score analysis showed that at TP levels higher than 0.030 mg/L, TP was no longer a limiting factor to periphyton. At lower levels, TP had an effect on periphyton after accounting for effects of the covarying stressors. While the covarying stressors were considered, they were not completely factored out. Therefore, the analysis does not prove causation and effects cannot be attributed to TP alone.

On a very coarse scale, we infer that TP criteria should be less than 0.030 mg/L. The stressor-response and reference distribution analyses indicated that criteria in the low valleys and plains should be higher than 0.030 mg/L TP. This apparent contradiction of the propensity score analysis should be further explored.

Specific results from the propensity score classes with lower levels of covarying stress were not transferable to specific sites or even categories of sites. Because of the high correlation between TP and TN overall and in the propensity score classes, we also infer that TN has some effect on periphyton up to a certain (unidentified) upper limit at which nutrients no longer have a limiting or promoting effect. The propensity score analysis was only performed to illustrate nutrient effects on periphyton. A second analysis with macroinvertebrate responses was not performed due to time constraints and because the indirect effects of nutrients on periphyton and then on macroinvertebrates would complicate the analysis to a degree that would confound interpretation.

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Appendix A.

Correlations – benthic/nutrient

Table A-1. Spearman Correlation between biological metrics and environmental variables in different site classes; p-value<0.05 *, <0.01 **, <0.001 ***.

Metric	Bioregion	SRP	TKN	TOTALN	TOTALP
MtnIndex	Mountains	-0.435*	-0.328***	-0.328***	-0.432***
LowValIndex	Mountains	-0.152	-0.022	-0.036	-0.145**
PlainsIndex	Mountains	-0.315	-0.127*	-0.212***	-0.123*
O.E_p.half	Mountains	-0.391	-0.332***	-0.337***	-0.329***
EPTTax	Mountains	-0.227	-0.246***	-0.293***	-0.325***
EphemTax	Mountains	-0.161	-0.251***	-0.26***	-0.264***
PlecTax	Mountains	-0.507**	-0.291***	-0.321***	-0.393***
TrchR300	Mountains	0.121	-0.135*	-0.199***	-0.202***
EPTPct	Mountains	-0.239	-0.313***	-0.279***	-0.384***
EPTnoHBPct	Mountains	-0.3	-0.276***	-0.274***	-0.357***
NonInsPct	Mountains	0.083	0.24***	0.206***	0.267***
CrusMolPct	Mountains	0.293	0.254***	0.203***	0.421***
tTanypodPct	Mountains	-0.344	0.301***	0.126*	0.211***
tNonInsPct	Mountains	0.083	0.24***	0.206***	0.267***
tEPTnoHBPct	Mountains	-0.3	-0.276***	-0.274***	-0.357***
tMidgePct	Mountains	0.274	0.208***	0.138*	0.111*
tCrusMolPct	Mountains	0.293	0.254***	0.203***	0.421***
tOrth2MidgPct	Mountains	0.17	-0.044	0.004	-0.132**
Orth2MidgPct	Mountains	0.17	-0.044	0.004	-0.132**
FiltCollPct	Mountains	0.349	0.168**	0.199***	0.209***
TanypodPct	Mountains	-0.344	0.301***	0.126*	0.211***
CllctPct	Mountains	0.263	0.158**	0.175**	0.156**
FiltrPct	Mountains	0.133	0.148*	0.073	0.162**
PredPct	Mountains	-0.093	0.056	0.014	0.021
ScrapPct	Mountains	0.163	-0.009	-0.01	-0.084
MidgePct	Mountains	0.274	0.208***	0.138*	0.111*
PredPctM	Mountains	-0.093	0.058	0.015	0.017
PredPctLV	Mountains	-0.093	0.058	0.015	0.017
HBI	Mountains	0.29	0.288***	0.262***	0.382***
ShredderTax	Mountains	-0.201	-0.1	-0.187***	-0.169***
PredatorTax	Mountains	-0.2	-0.107	-0.212***	-0.171***
CllctTax	Mountains	-0.04	0.018	-0.045	0.113*
FiltrTax	Mountains	0.235	-0.066	-0.096	0.071

Metric	Bioregion	SRP	TKN	TOTALN	TOTALP
PredTax	Mountains	-0.2	-0.109	-0.212***	-0.17***
ScrapTax	Mountains	-0.089	-0.15*	-0.178***	-0.174***
ShredTax	Mountains	-0.201	-0.101	-0.187***	-0.17***
BrrwrTaxPct	Mountains	0.163	0.25***	0.243***	0.382***
tFiltCollPct	Mountains	0.349	0.168**	0.199***	0.209***
tEPTPct	Mountains	-0.239	-0.313***	-0.279***	-0.384***
tPredPctM	Mountains	-0.093	0.058	0.015	0.017
tShredPct	Mountains	-0.096	-0.141*	-0.206***	-0.142**
tPredPctLV	Mountains	-0.093	0.058	0.015	0.017
tCllctPct	Mountains	0.263	0.158**	0.175**	0.156**
tFiltrPct	Mountains	0.133	0.148*	0.073	0.162**
tPredPct	Mountains	-0.093	0.056	0.014	0.021
tScrapPct	Mountains	0.163	-0.009	-0.01	-0.084
MtnIndex	LowValley	-0.5	-0.333***	-0.274***	-0.415***
LowValIndex	LowValley	1	-0.22*	-0.217**	-0.371***
PlainsIndex	LowValley	-1	-0.13	-0.163*	-0.214**
O.E_p.half	LowValley	0.5	-0.119	0.015	-0.187*
EPTTax	LowValley	-1	-0.275**	-0.275***	-0.372***
EphemTax	LowValley	-0.5	-0.278**	-0.257***	-0.411***
PlecTax	LowValley	-1	-0.184	-0.215**	-0.254***
TrchR300	LowValley	1	-0.11	-0.139	-0.233**
EPTPct	LowValley	0.5	-0.302**	-0.13	-0.33***
EPTnoHBPct	LowValley	-0.5	-0.333***	-0.29***	-0.337***
NonInsPct	LowValley	-1	0.119	0.114	0.229**
CrusMolPct	LowValley	1	0.254**	0.26***	0.441***
tTanypodPct	LowValley	0.5	0.027	0.032	0.144*
tNonInsPct	LowValley	-1	0.119	0.114	0.229**
tEPTnoHBPct	LowValley	-0.5	-0.333***	-0.29***	-0.337***
tMidgePct	LowValley	0.5	0.109	0.018	-0.051
tCrusMolPct	LowValley	1	0.254**	0.26***	0.441***
tOrth2MidgPct	LowValley	-0.5	-0.143	-0.058	0.048
Orth2MidgPct	LowValley	-0.5	-0.143	-0.058	0.048
FiltCollPct	LowValley	1	0.132	0.142	0.082
TanypodPct	LowValley	0.5	0.027	0.032	0.144*
CllctPct	LowValley	-0.5	0.035	0.061	0.029
FiltrPct	LowValley	0.5	0.125	0.069	-0.011
PredPct	LowValley	0.5	-0.044	-0.025	-0.08
ScrapPct	LowValley	-0.5	-0.05	-0.08	-0.005
MidgePct	LowValley	0.5	0.109	0.018	-0.051
PredPctM	LowValley	0.5	-0.044	-0.025	-0.082
PredPctLV	LowValley	0.5	-0.044	-0.025	-0.082
HBI	LowValley	0.5	0.372***	0.32***	0.299***

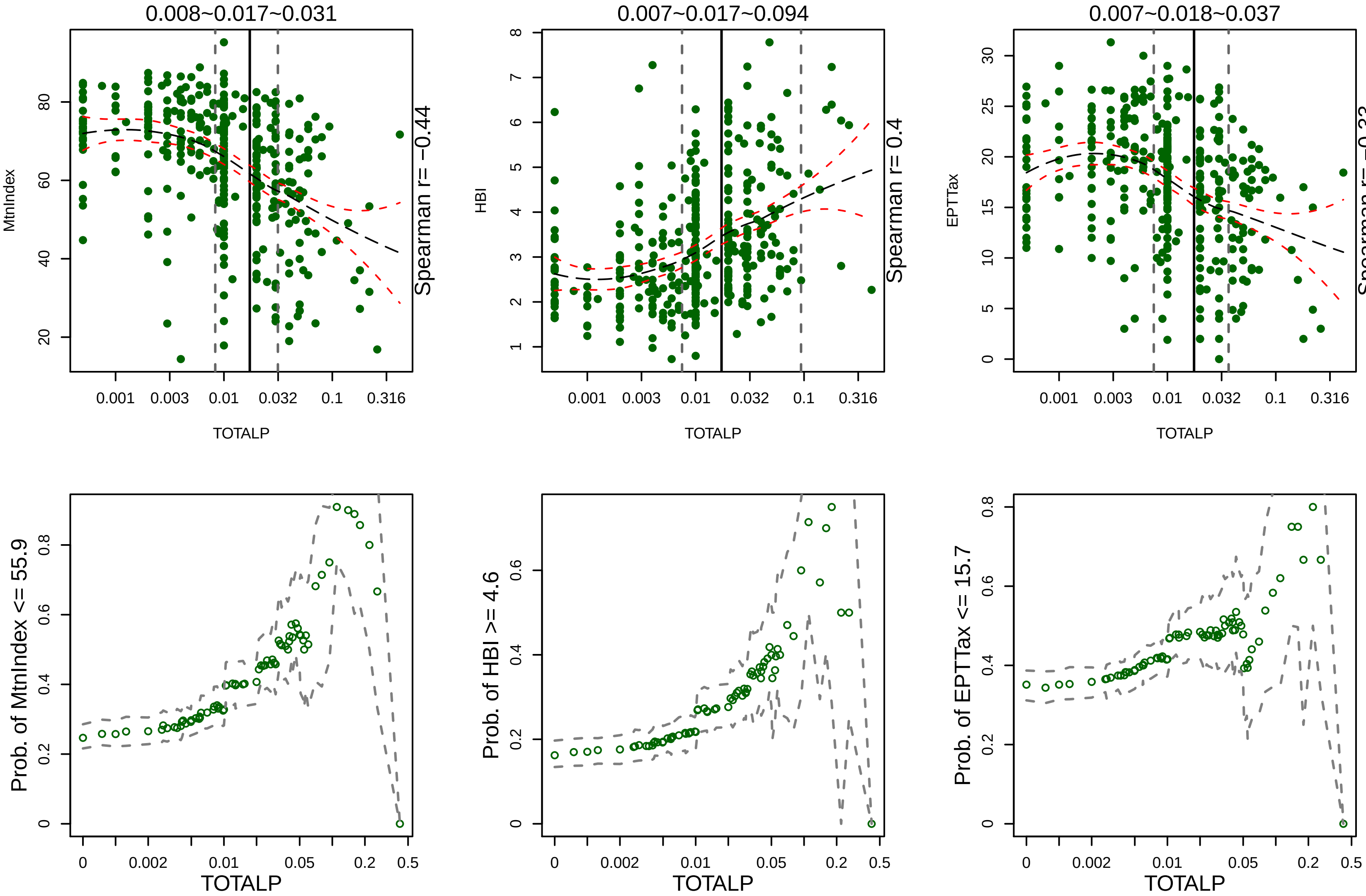
Metric	Bioregion	SRP	TKN	TOTALN	TOTALP
ShredderTax	LowValley	-1	-0.045	-0.09	0.06
PredatorTax	LowValley	-0.5	-0.159	-0.2*	-0.144*
CllctTax	LowValley	-1	-0.029	-0.072	-0.044
FiltrTax	LowValley	0.5	0.051	0.02	-0.047
PredTax	LowValley	-0.5	-0.159	-0.204**	-0.142
ScrapTax	LowValley	-0.5	-0.234*	-0.192*	-0.287***
ShredTax	LowValley	-1	-0.045	-0.09	0.06
BrrwrTaxPct	LowValley	-1	0.243*	0.146	0.372***
tFiltCollPct	LowValley	1	0.132	0.142	0.082
tEPTPct	LowValley	0.5	-0.302**	-0.13	-0.33***
tPredPctM	LowValley	0.5	-0.044	-0.025	-0.082
tShredPct	LowValley	-1	-0.162	-0.108	0.028
tPredPctLV	LowValley	0.5	-0.044	-0.025	-0.082
tCllctPct	LowValley	-0.5	0.035	0.061	0.029
tFiltrPct	LowValley	0.5	0.125	0.069	-0.011
tPredPct	LowValley	0.5	-0.044	-0.025	-0.08
tScrapPct	LowValley	-0.5	-0.05	-0.08	-0.005
MtnIndex	Plains	-0.365**	-0.446***	-0.444***	-0.339***
LowValIndex	Plains	-0.312*	-0.174**	-0.198***	-0.097
PlainsIndex	Plains	-0.093	-0.012	-0.055	0.003
O.E_p.half	Plains	0.03	0.035	-0.065	-0.038
EPTTax	Plains	-0.174	-0.516***	-0.512***	-0.391***
EphemTax	Plains	-0.2	-0.476***	-0.474***	-0.354***
PlecTax	Plains	-0.184	-0.455***	-0.428***	-0.381***
TrchR300	Plains	-0.143	-0.469***	-0.444***	-0.36***
EPTPct	Plains	-0.246	-0.485***	-0.439***	-0.305***
EPTnoHBPct	Plains	-0.191	-0.393***	-0.385***	-0.249***
NonInsPct	Plains	0.347**	0.384***	0.331***	0.233***
CrusMolPct	Plains	0.312*	0.399***	0.357***	0.177***
tTanypodPct	Plains	-0.13	0.117	0.079	0.107*
tNonInsPct	Plains	0.347**	0.384***	0.331***	0.233***
tEPTnoHBPct	Plains	-0.191	-0.393***	-0.385***	-0.249***
tMidgePct	Plains	-0.254	-0.026	-0.051	-0.094
tCrusMolPct	Plains	0.312*	0.399***	0.357***	0.177***
tOrth2MidgPct	Plains	-0.027	-0.413***	-0.37***	-0.321***
Orth2MidgPct	Plains	-0.027	-0.413***	-0.37***	-0.321***
FiltCollPct	Plains	0.133	0.075	0.109*	0.024
TanypodPct	Plains	-0.13	0.117	0.079	0.107*
CllctPct	Plains	0.18	0.234***	0.214***	0.129*
FiltrPct	Plains	0.143	0.001	0.04	-0.045
PredPct	Plains	-0.078	0.341***	0.243***	0.19***
ScrapPct	Plains	-0.17	-0.49***	-0.475***	-0.391***

Metric	Bioregion	SRP	TKN	TOTALN	TOTALP
MidgePct	Plains	-0.254	-0.026	-0.051	-0.094
PredPctM	Plains	-0.078	0.34***	0.241***	0.189***
PredPctLV	Plains	-0.078	0.34***	0.241***	0.189***
HBI	Plains	0.226	0.547***	0.523***	0.422***
ShredderTax	Plains	-0.094	-0.2***	-0.269***	-0.129*
PredatorTax	Plains	0.3*	0.097	0.012	0.042
CllctTax	Plains	0.081	-0.26***	-0.322***	-0.231***
FiltrTax	Plains	0.188	-0.404***	-0.306***	-0.273***
PredTax	Plains	0.301*	0.096	0.011	0.039
ScrapTax	Plains	-0.17	-0.466***	-0.46***	-0.359***
ShredTax	Plains	-0.069	-0.202***	-0.27***	-0.124*
BrrwrTaxPct	Plains	-0.016	-0.011	0.026	0.138**
tFiltCollPct	Plains	0.133	0.075	0.109*	0.024
tEPTPct	Plains	-0.246	-0.485***	-0.439***	-0.305***
tPredPctM	Plains	-0.078	0.34***	0.241***	0.189***
tShredPct	Plains	-0.052	-0.177**	-0.239***	-0.112*
tPredPctLV	Plains	-0.078	0.34***	0.241***	0.189***
tCllctPct	Plains	0.18	0.234***	0.214***	0.129*
tFiltrPct	Plains	0.143	0.001	0.04	-0.045
tPredPct	Plains	-0.078	0.341***	0.243***	0.19***
tScrapPct	Plains	-0.17	-0.49***	-0.475***	-0.391***

Appendix B

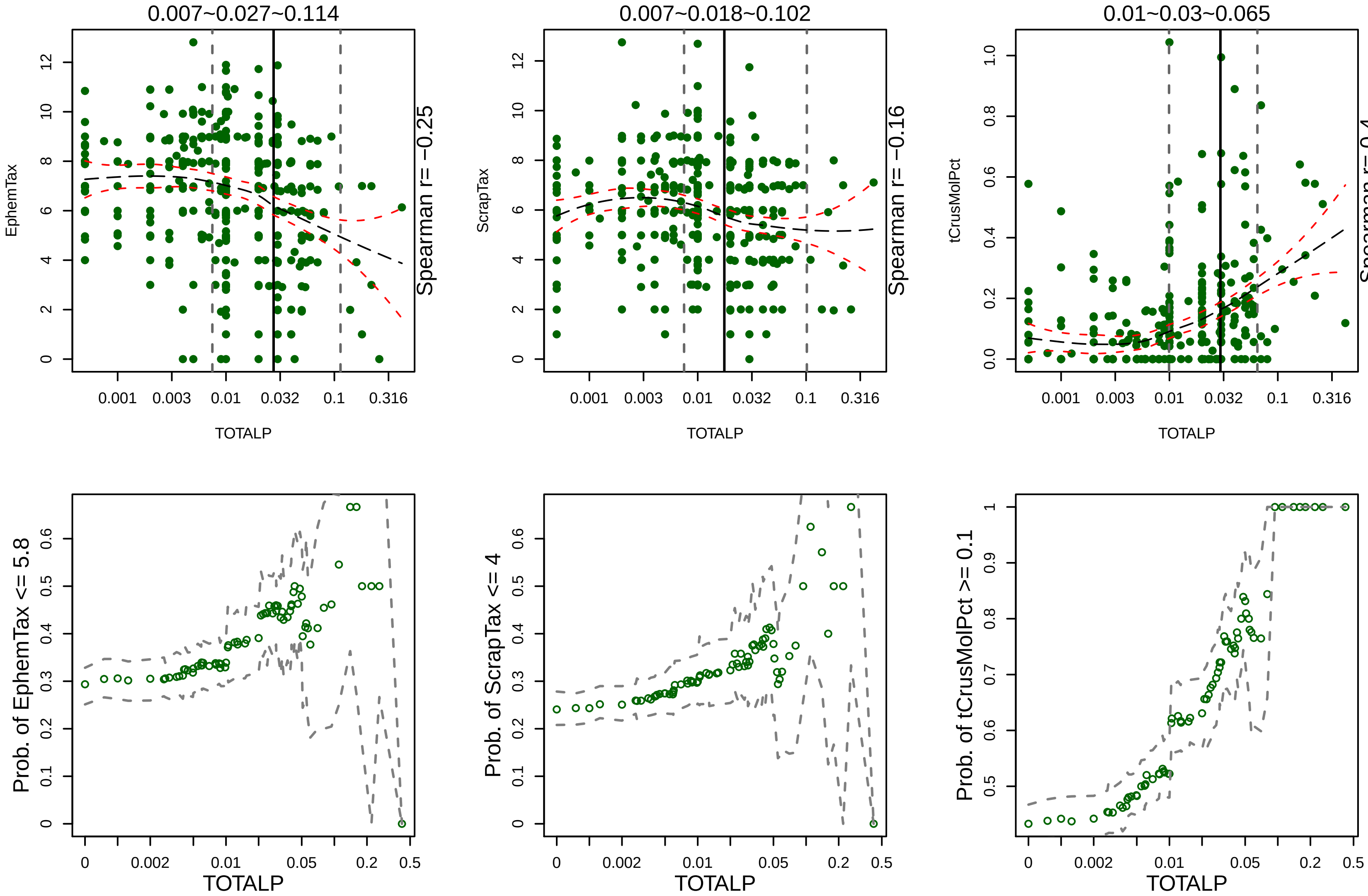
Benthic response plots

Macroinvertebrates vs. TP in Mountains: Kick and TarRiff Samples



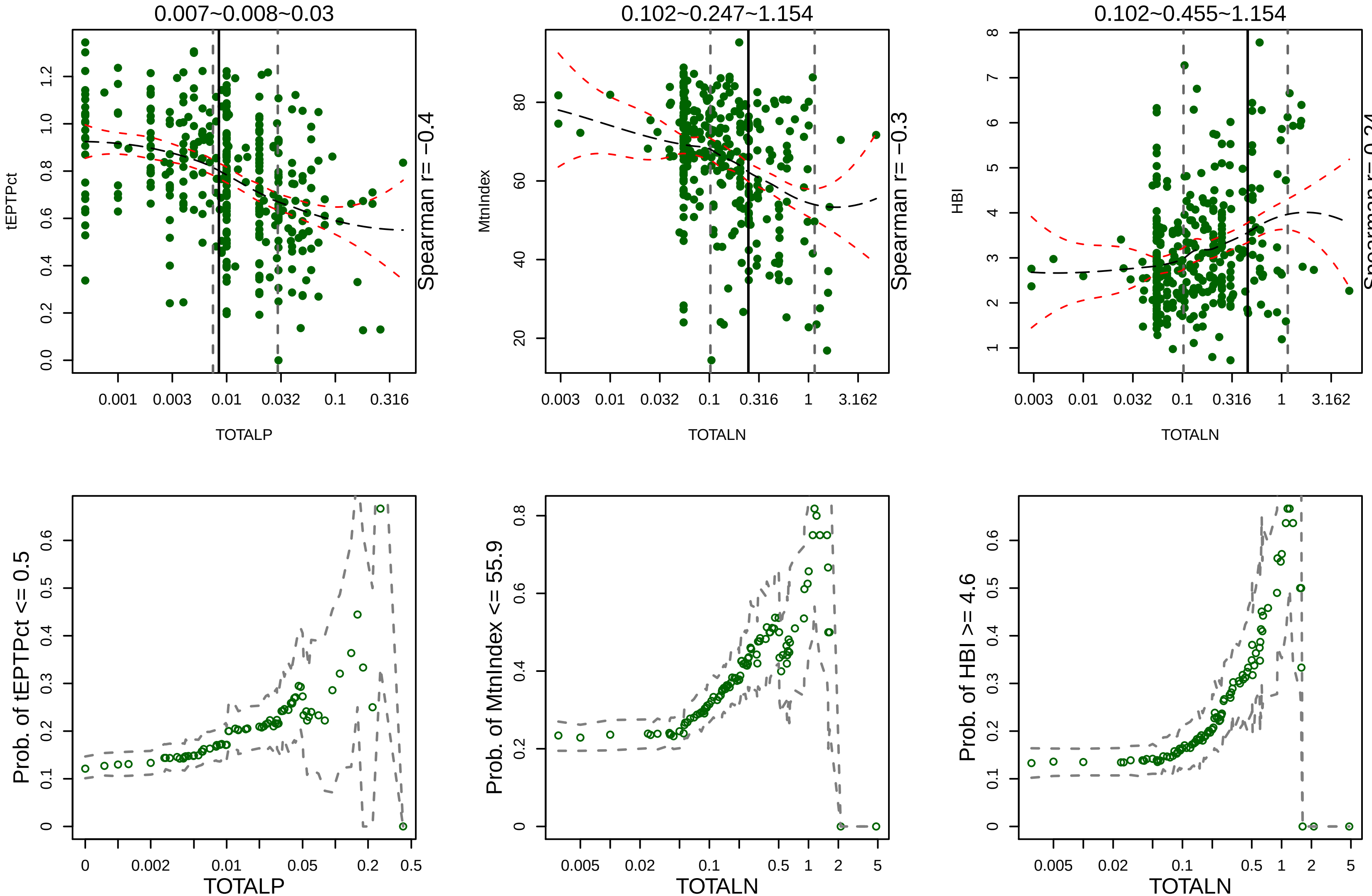
0007115

Macroinvertebrates vs. TP in Mountains: Kick and TarRiff Samples



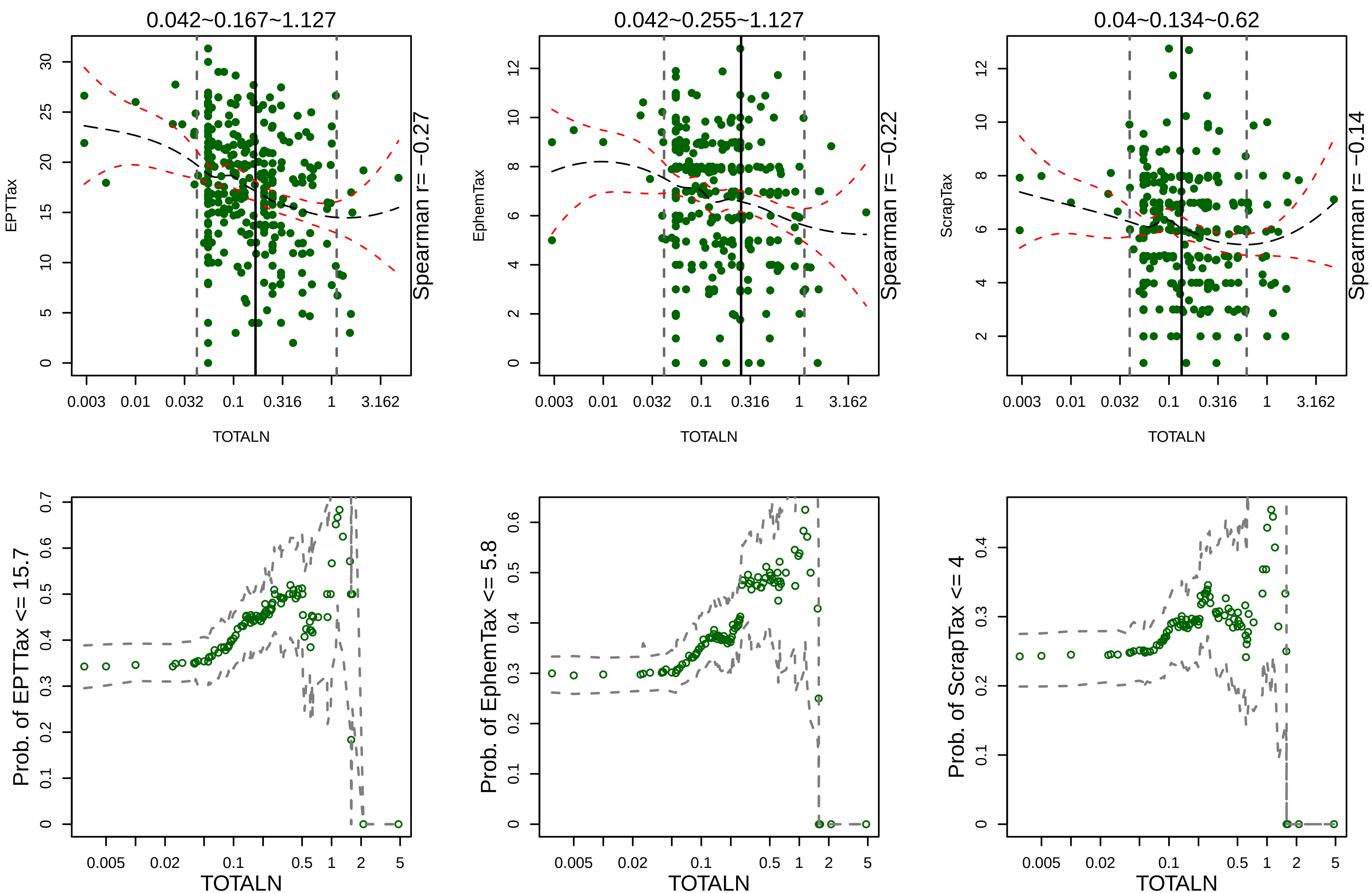
0007116

Macroinvertebrates vs. TP in Mountains: Kick and TarRiff Samples



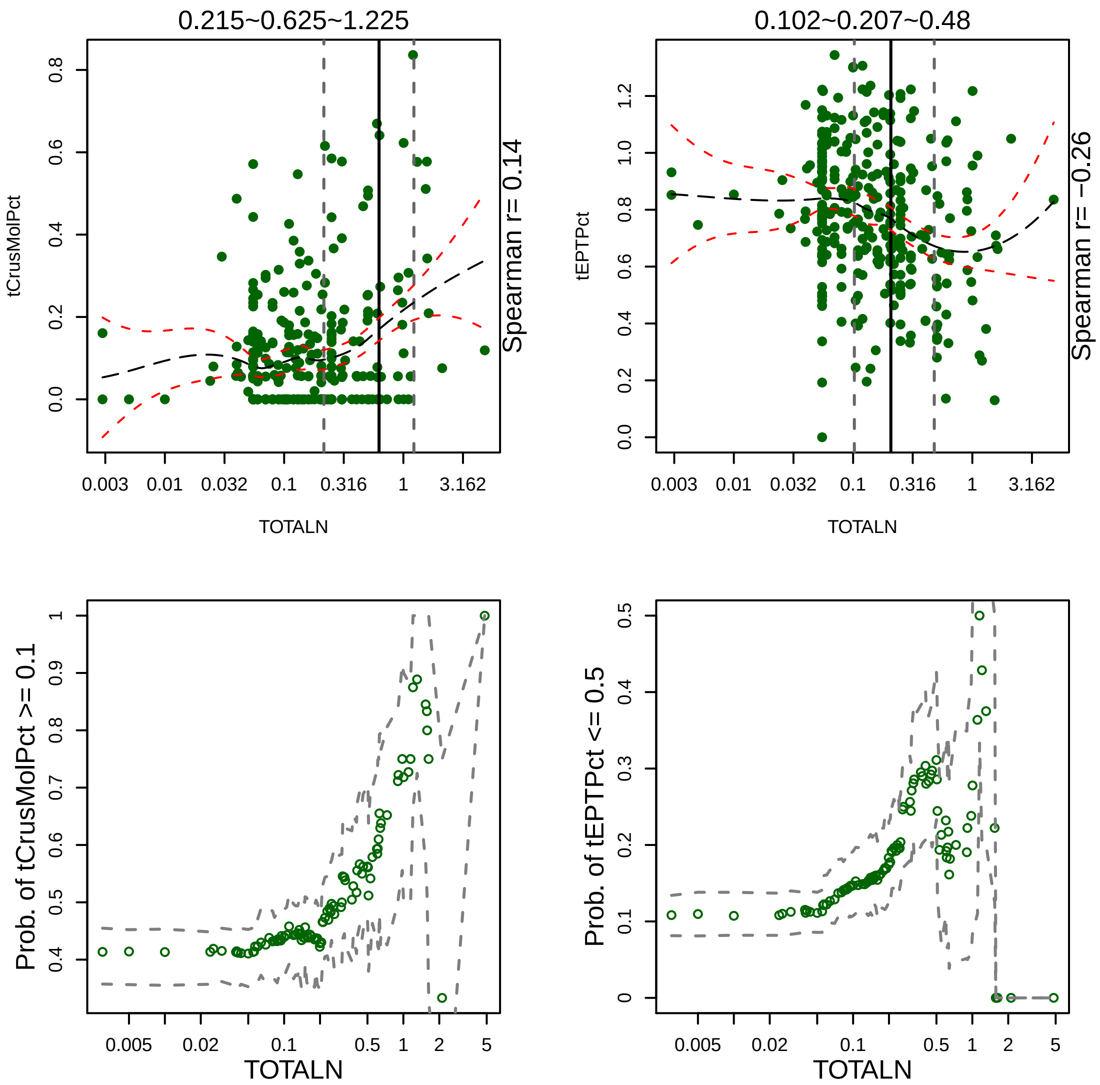
0007117

Macroinvertebrates vs. TP in Mountains: Kick and TarRiff Samples



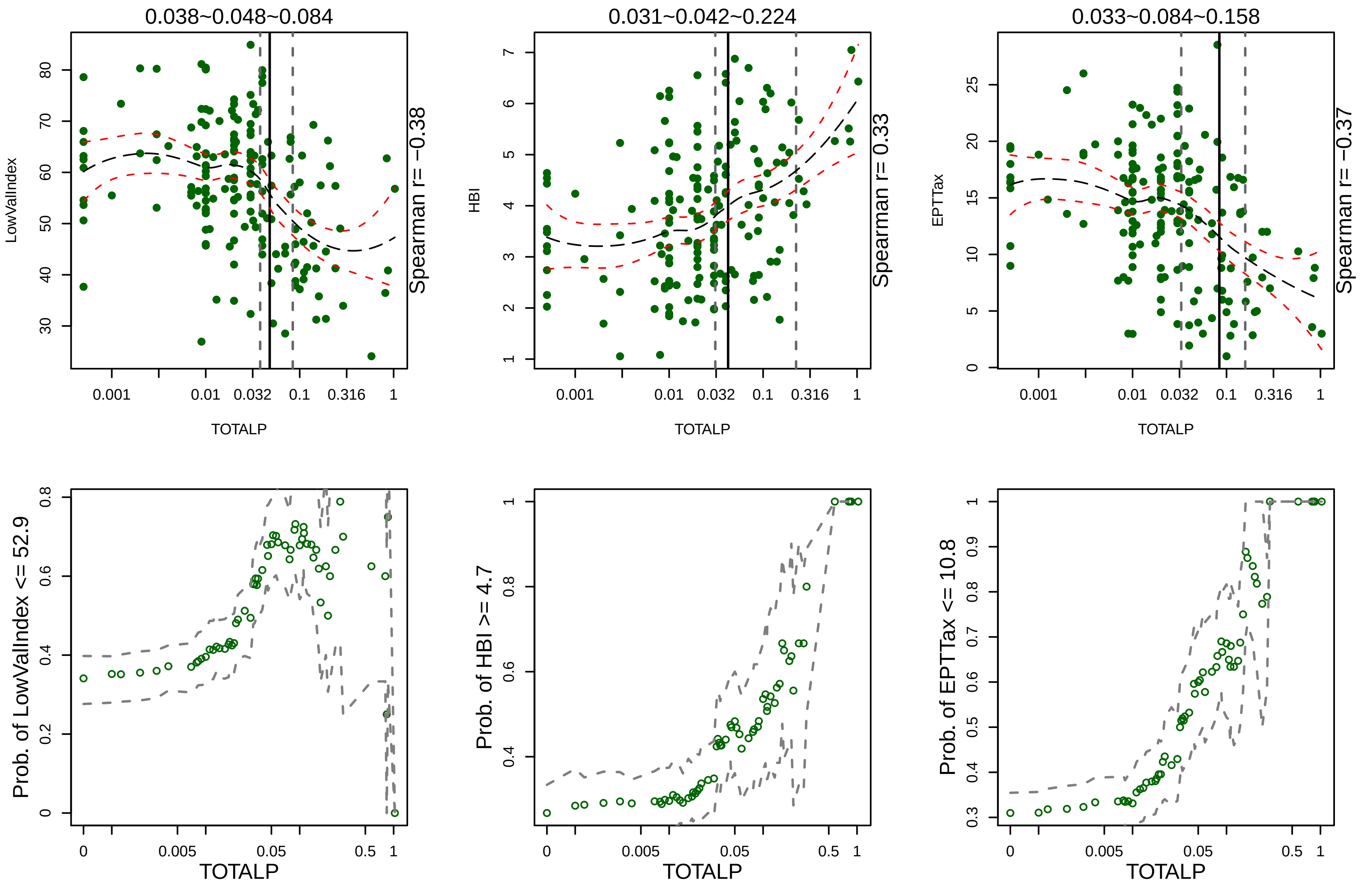
0007118

Macroinvertebrates vs. TP in Mountains: Kick and TarRiff Samples

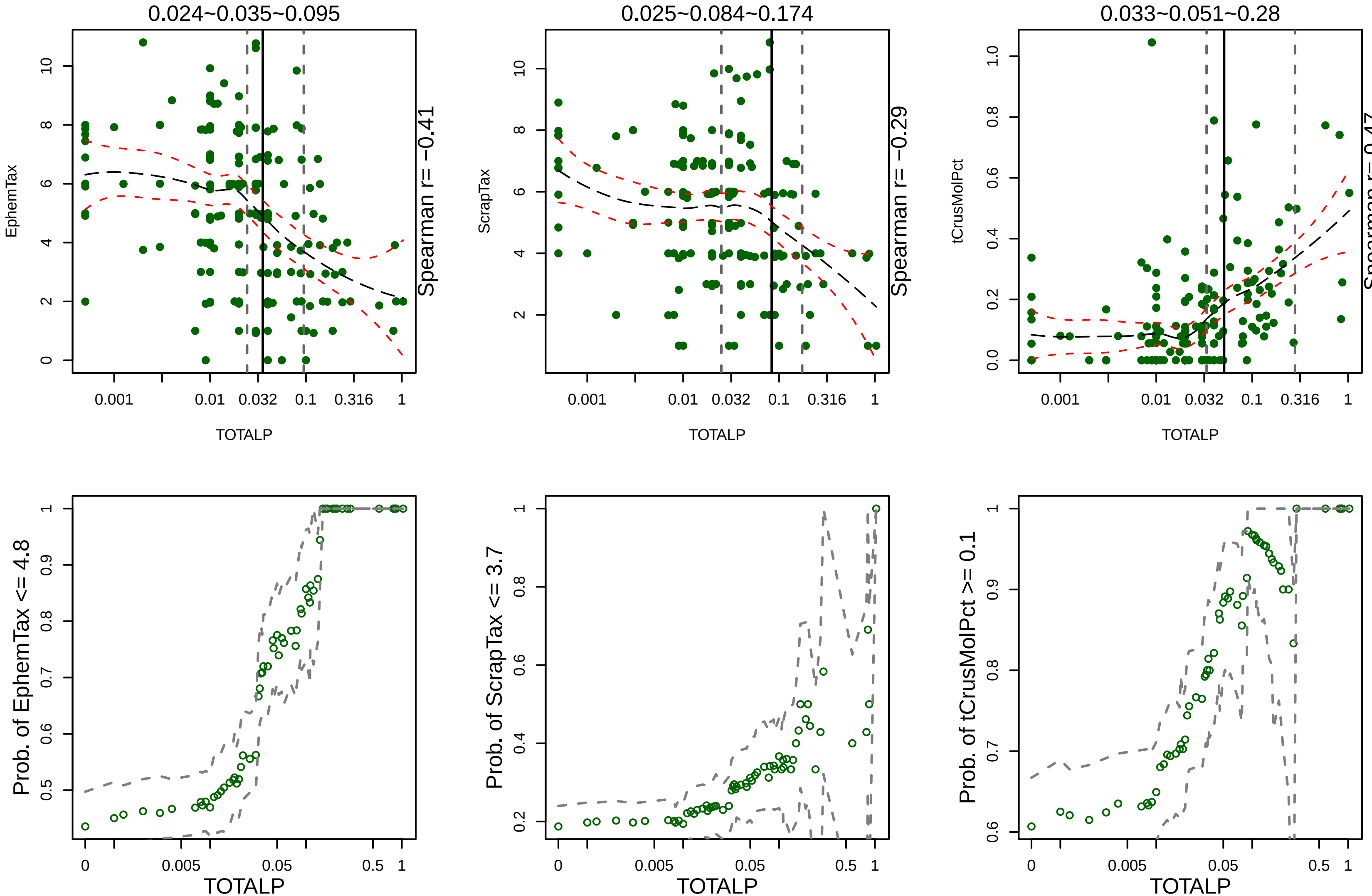


0007119

Macroinvertebrates response to total Phosphorus in Low Valleys

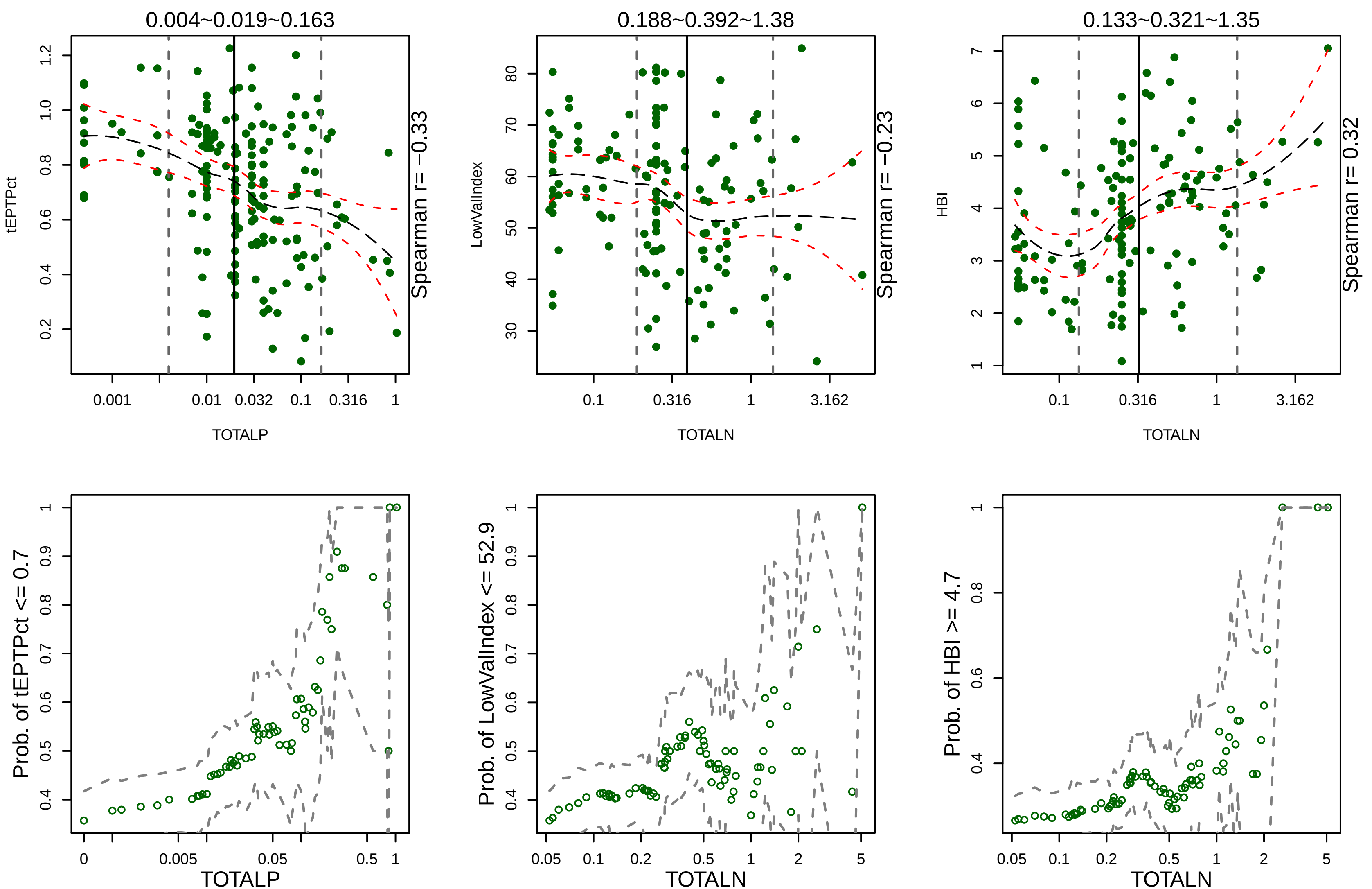


Macroinvertebrates response to total Phosphorus in Low Valleys



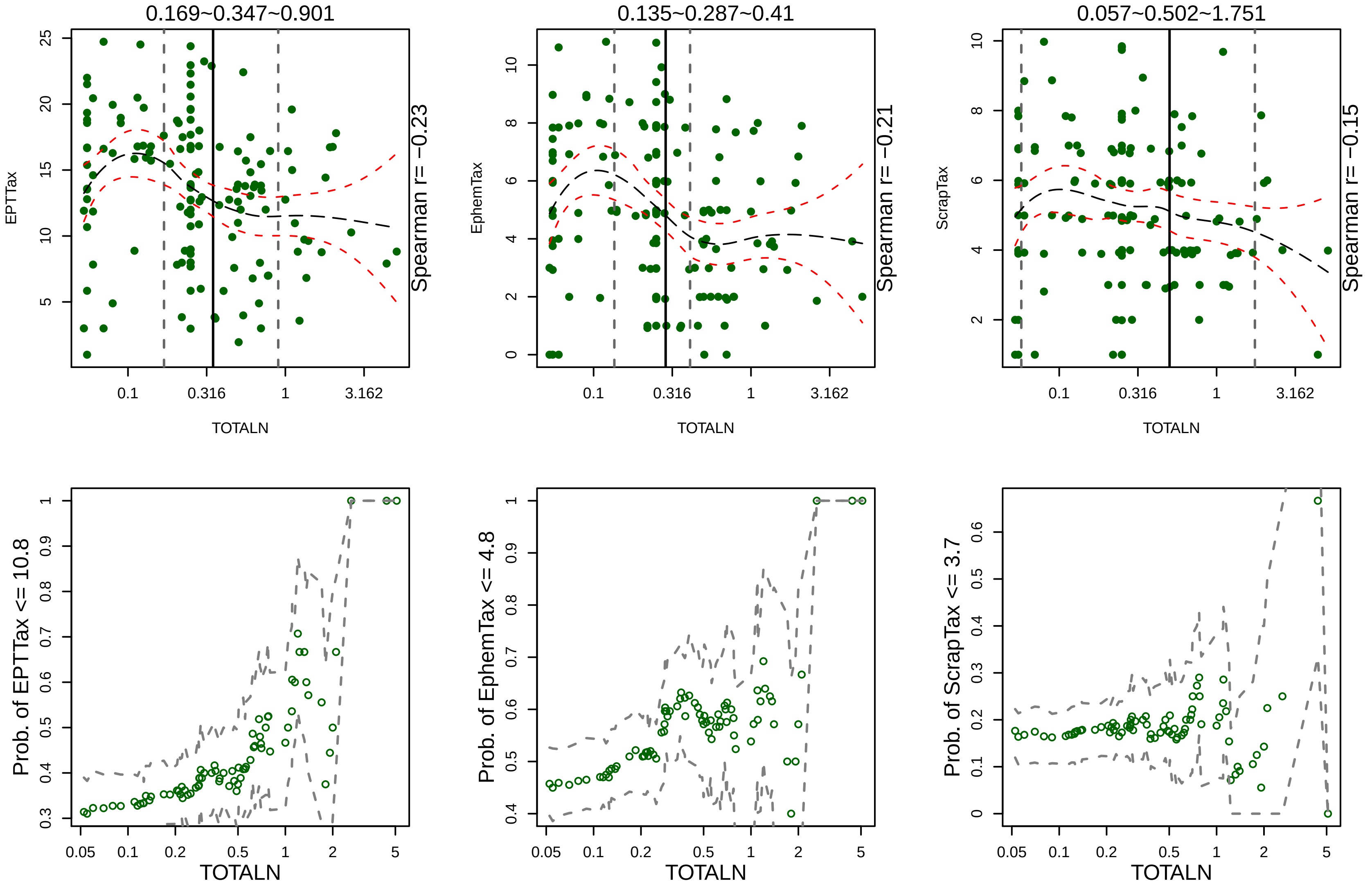
0007121

Macroinvertebrates response to total Phosphorus in Low Valleys

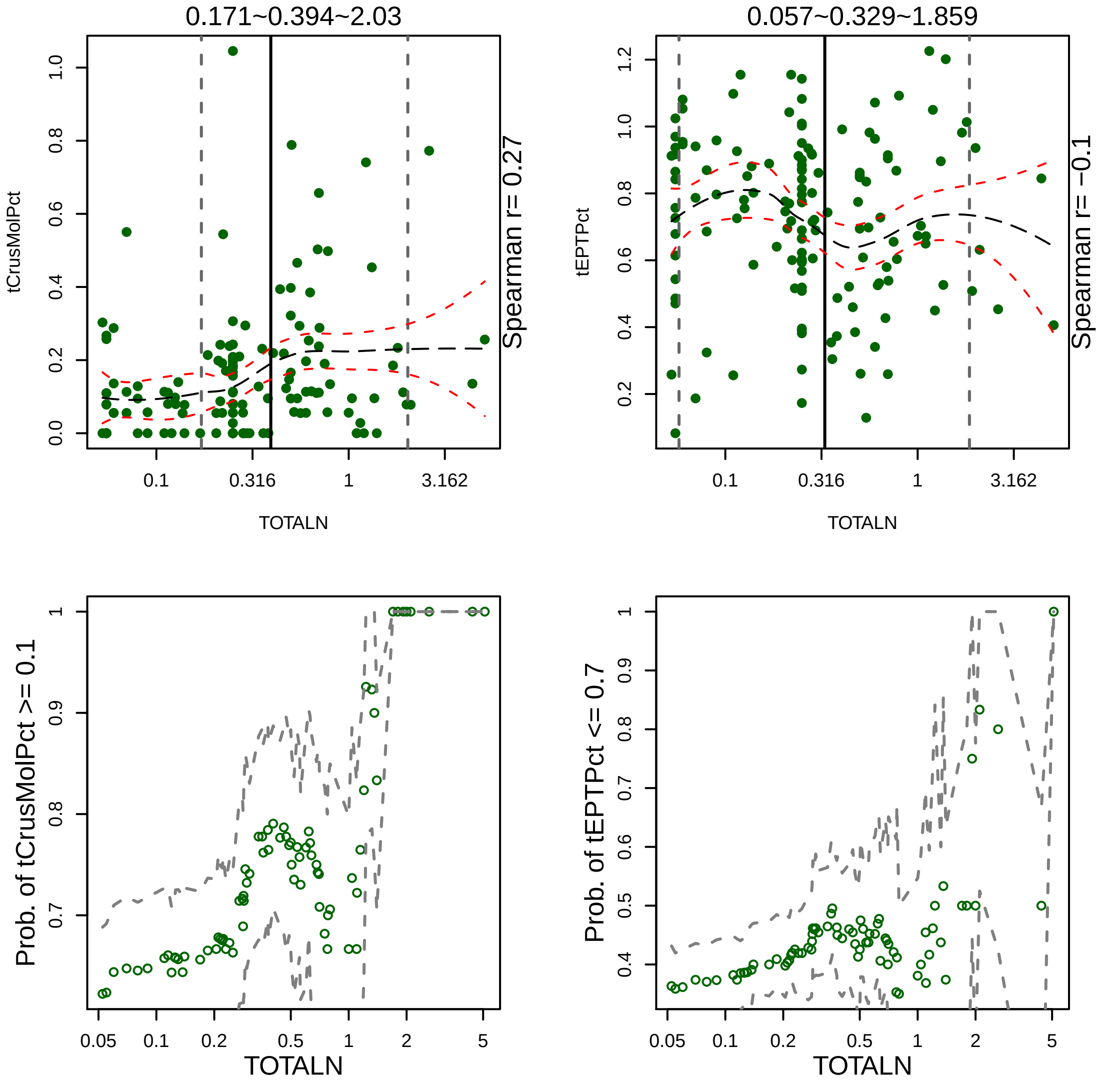


0007122

Macroinvertebrates response to total Phosphorus in Low Valleys

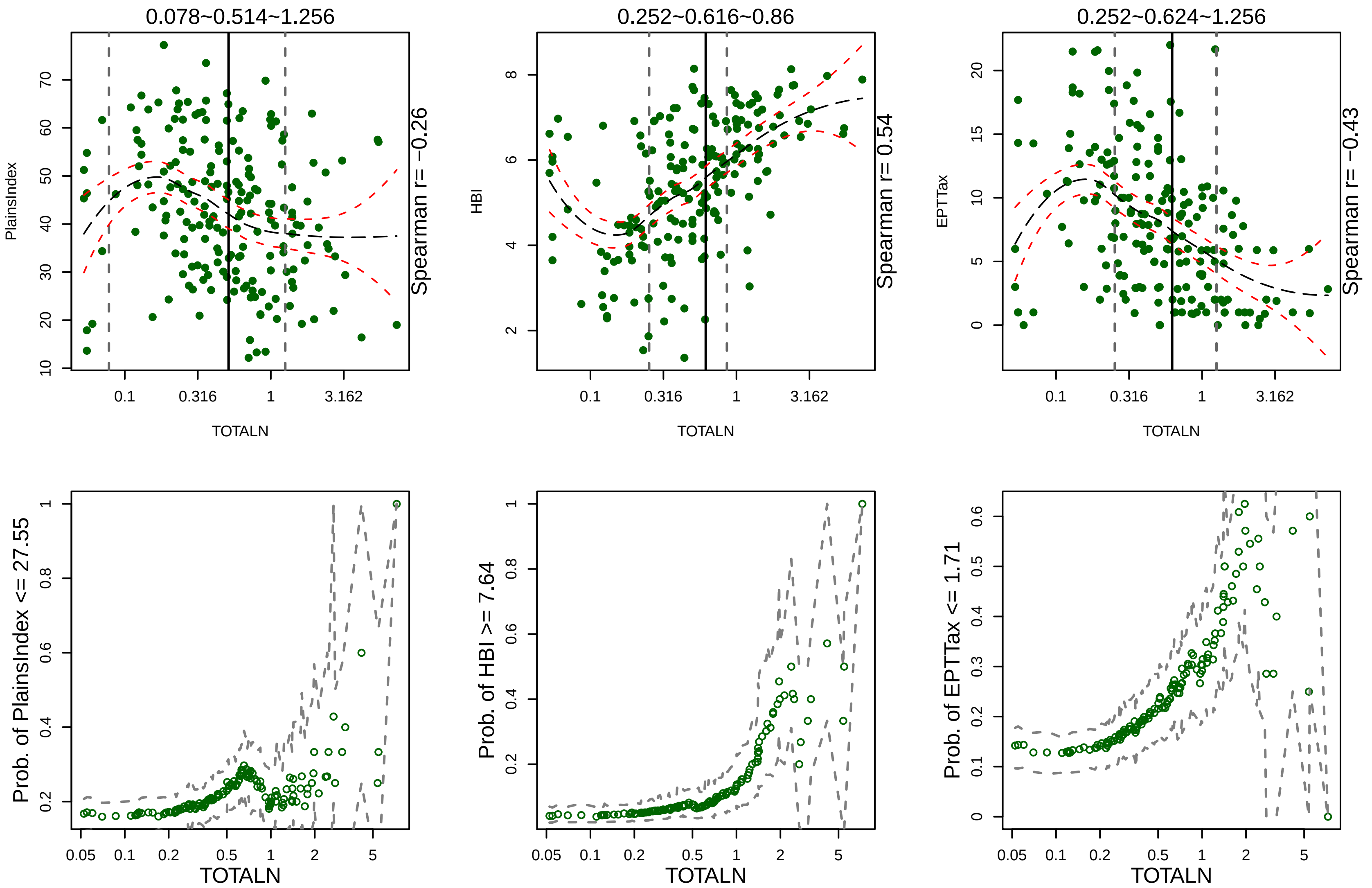


Macroinvertebrates response to total Phosphorus in Low Valleys



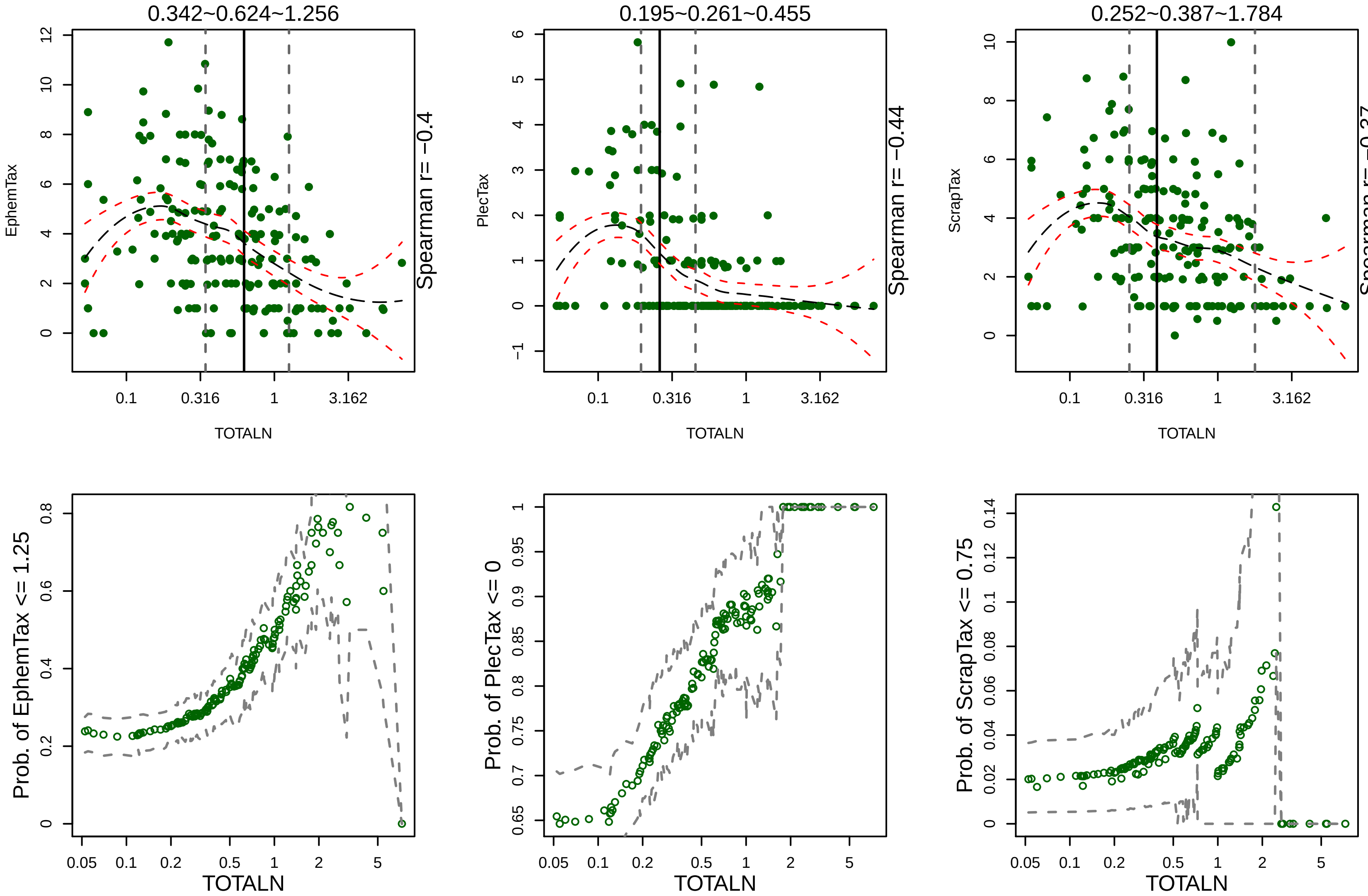
0007124

Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

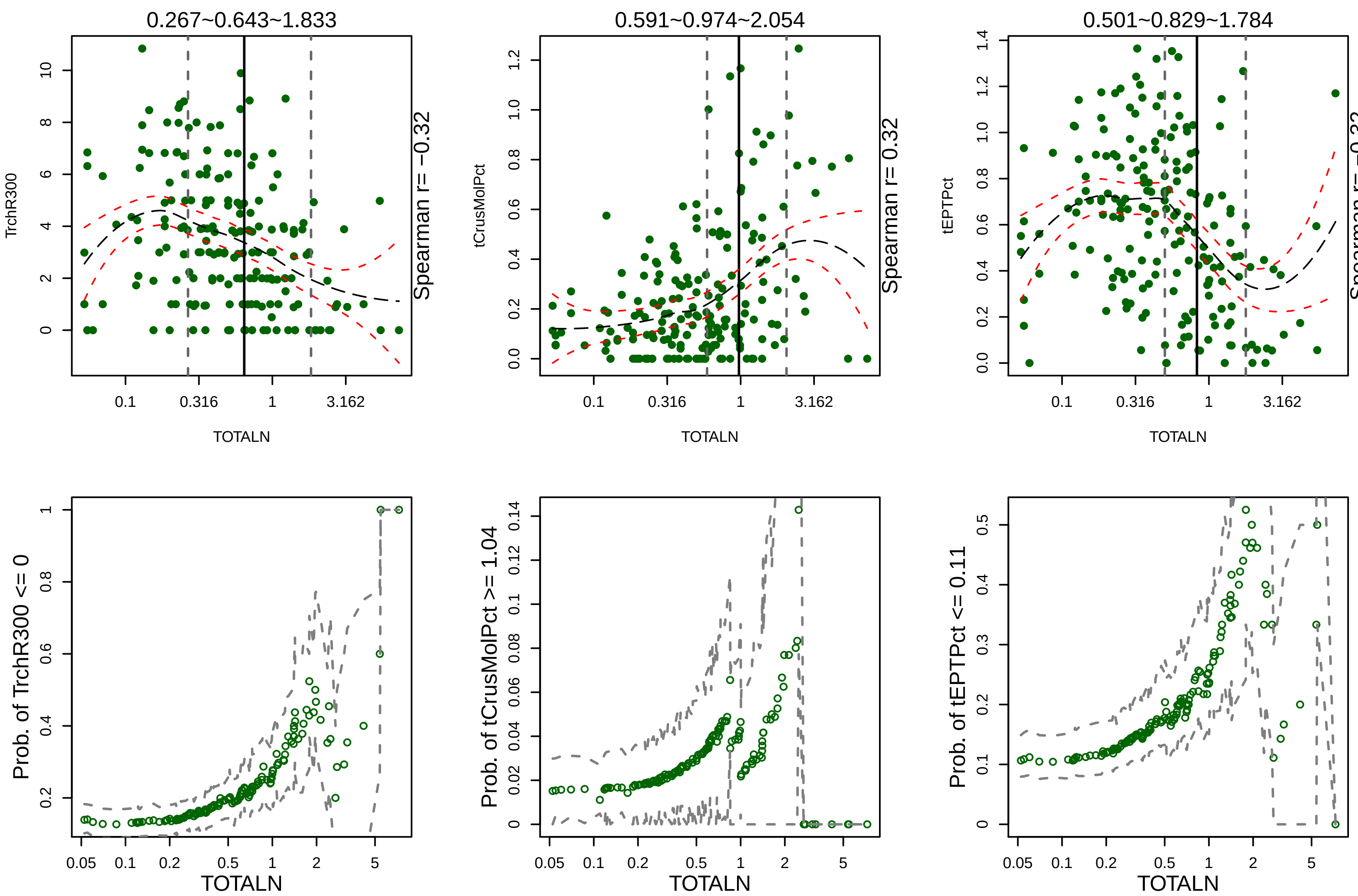


0007125

Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

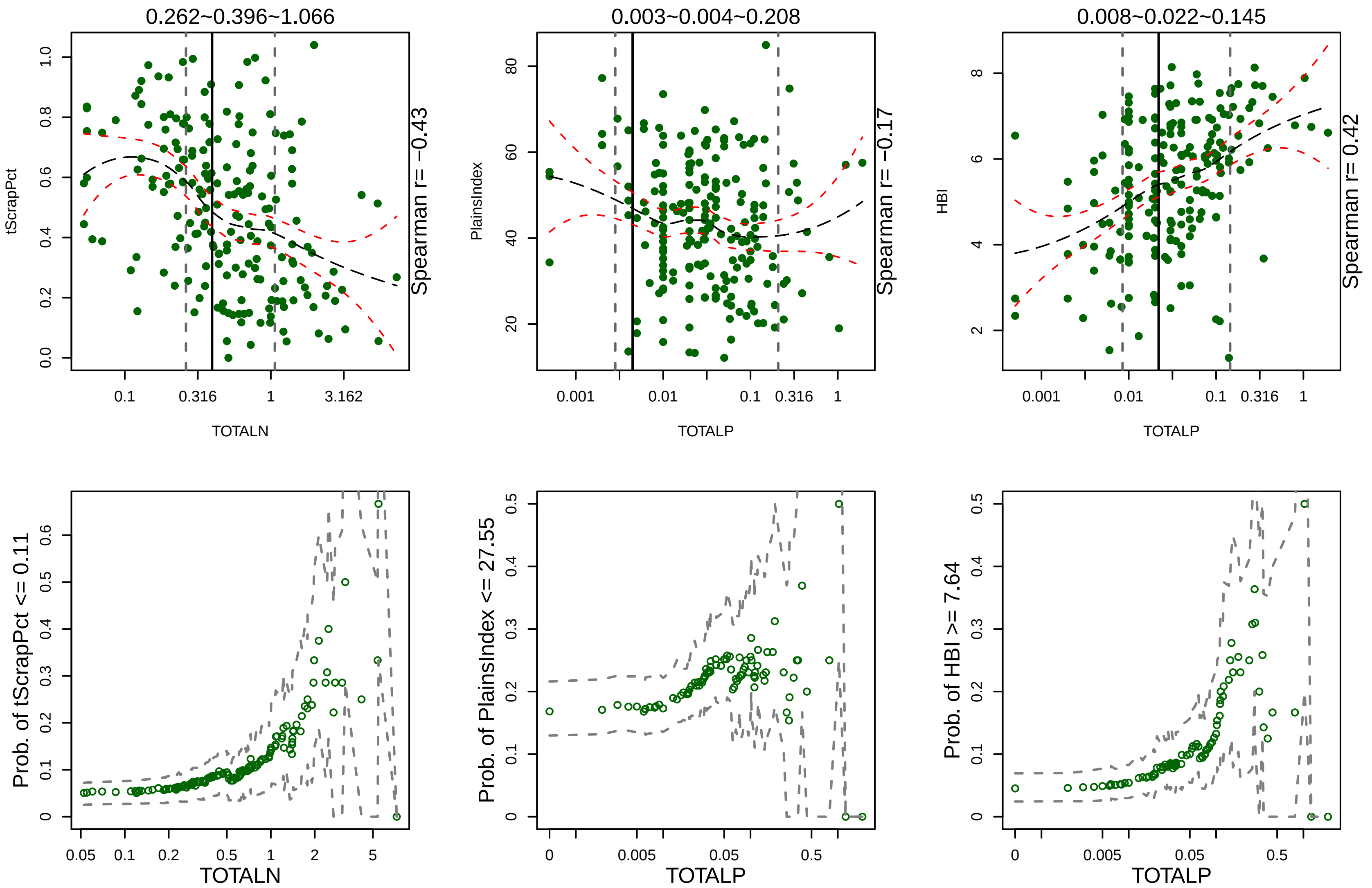


Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

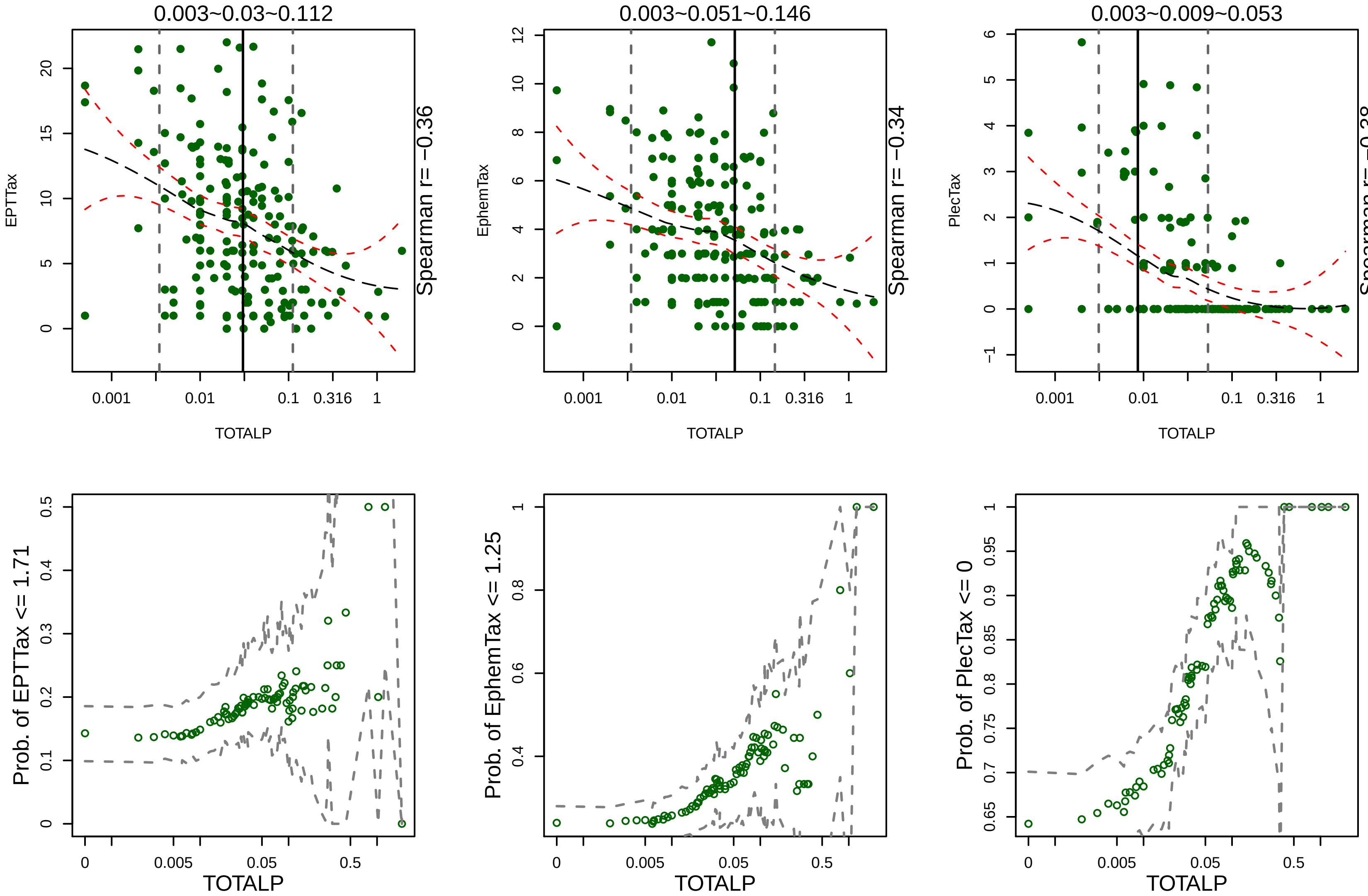


0007127

Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

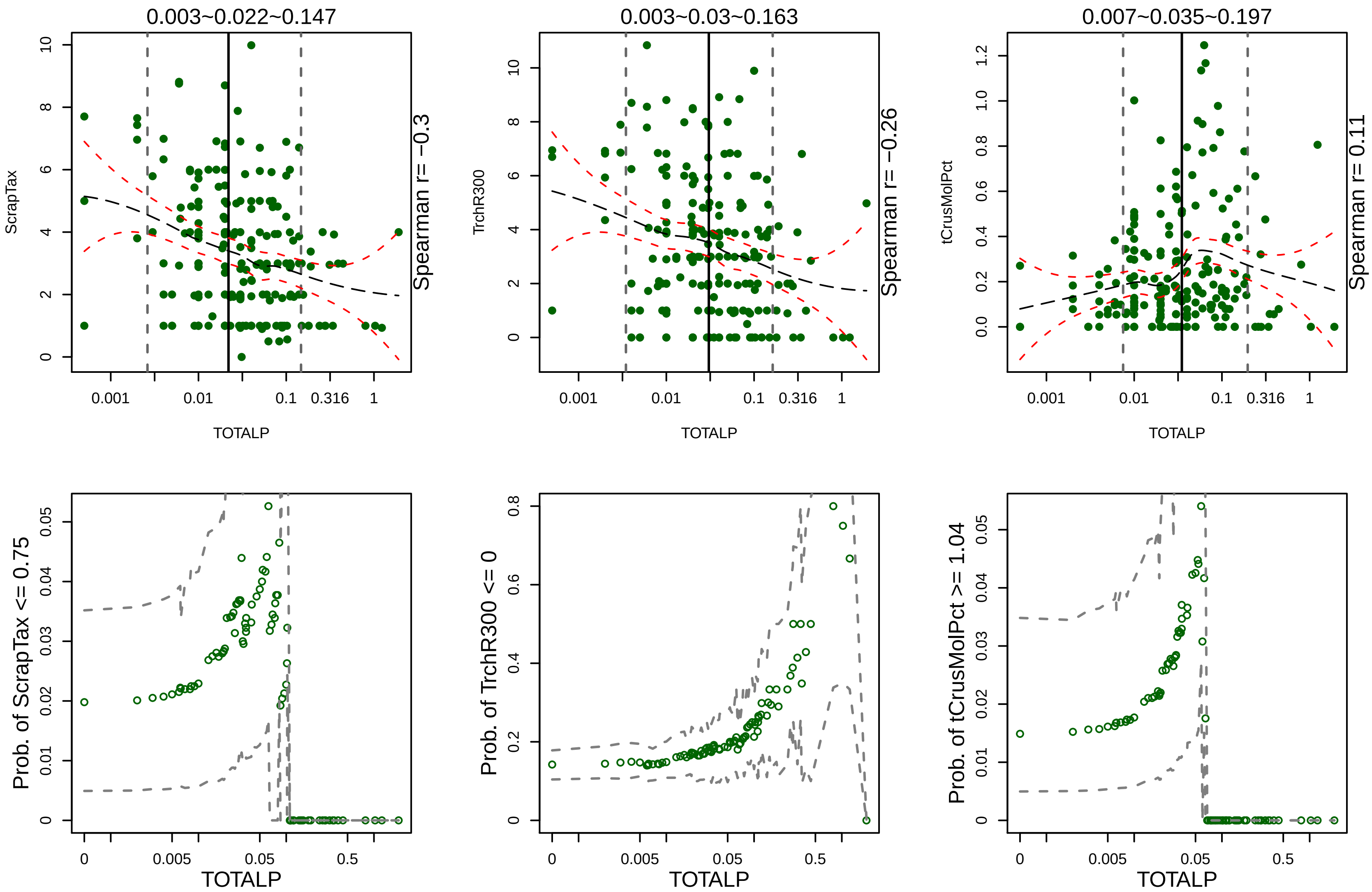


Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

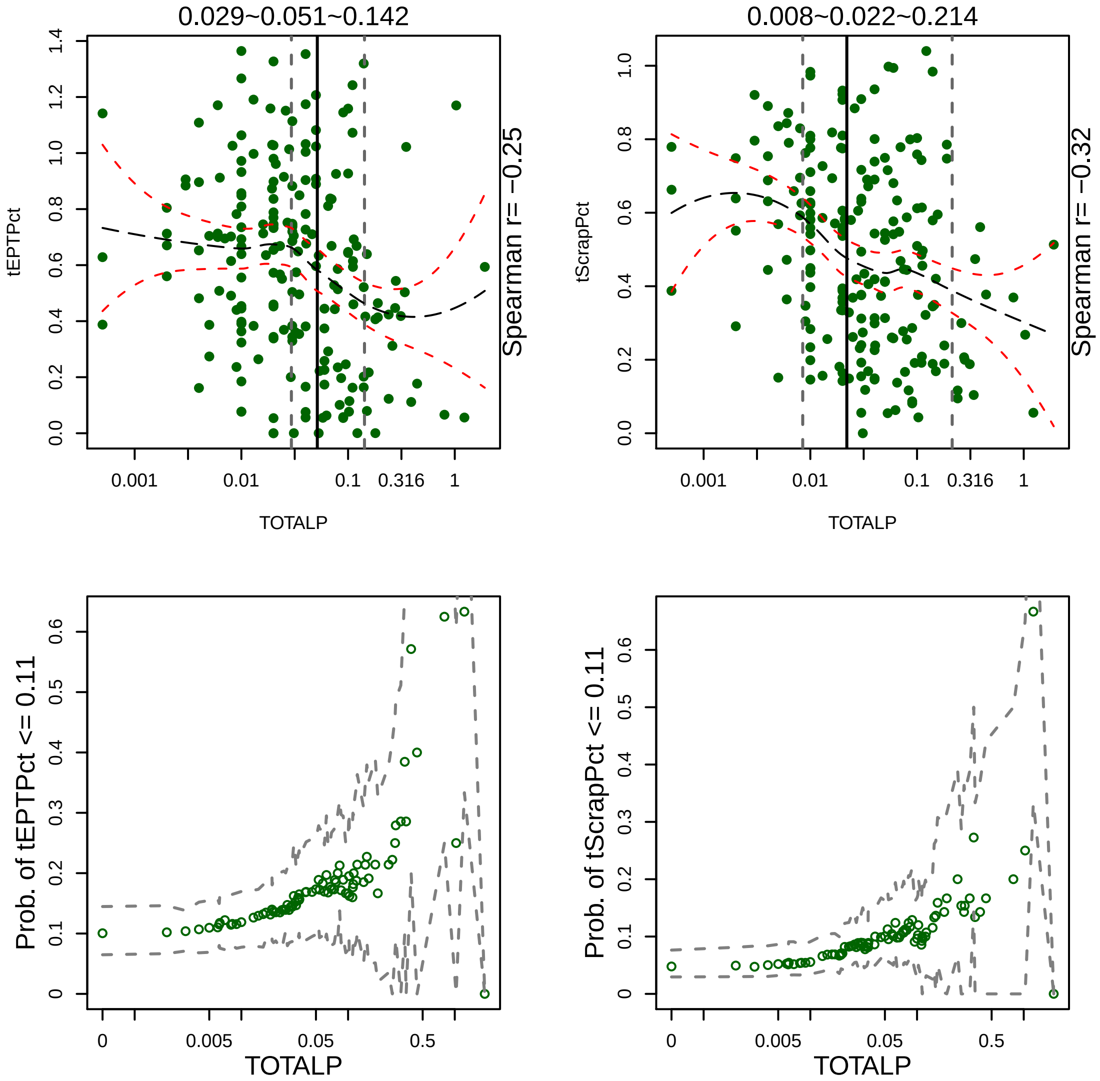


0007129

Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

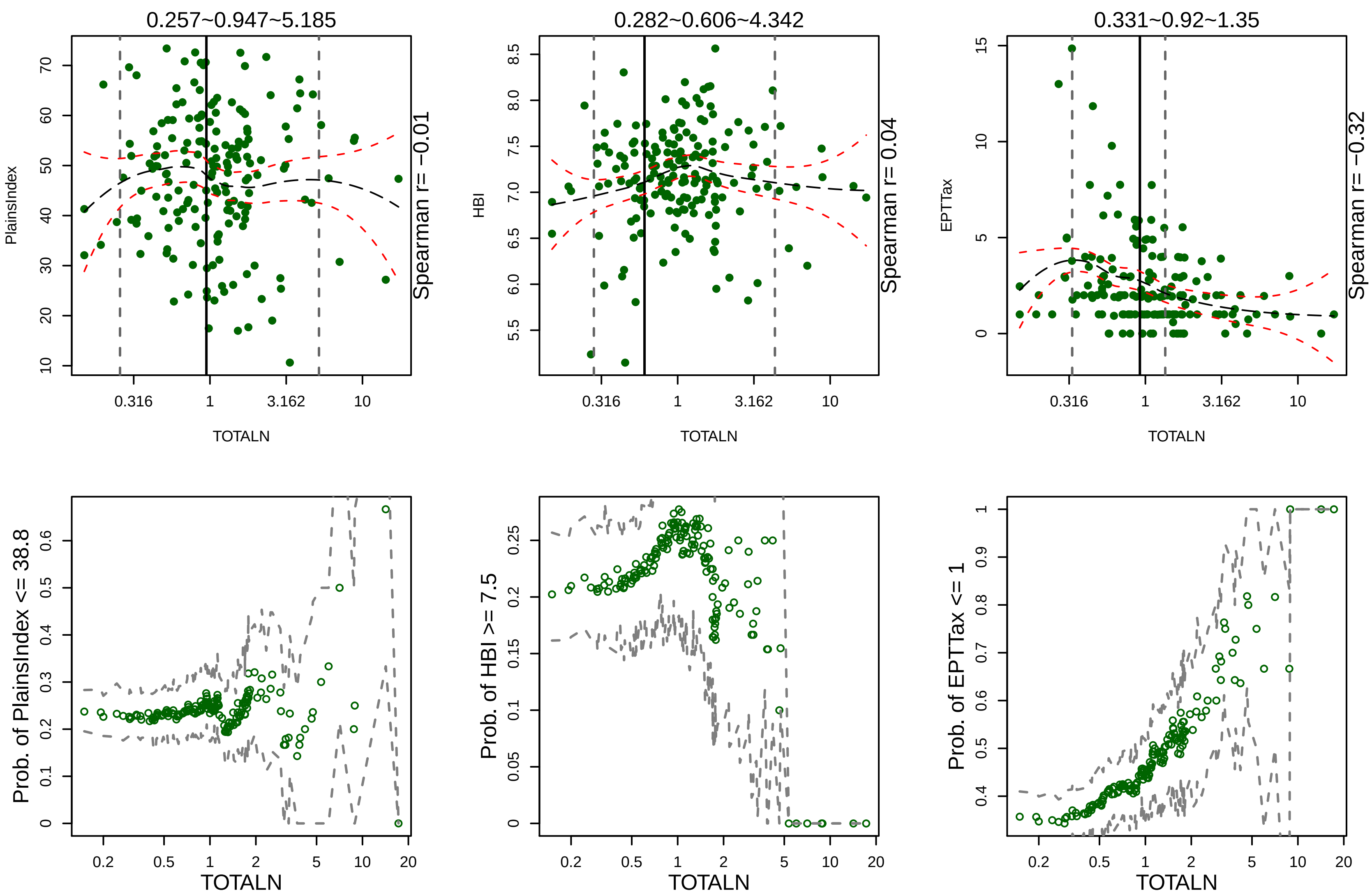


Macroinvertebrates vs. nutrients in Plains: Kick and TarRiff Samples

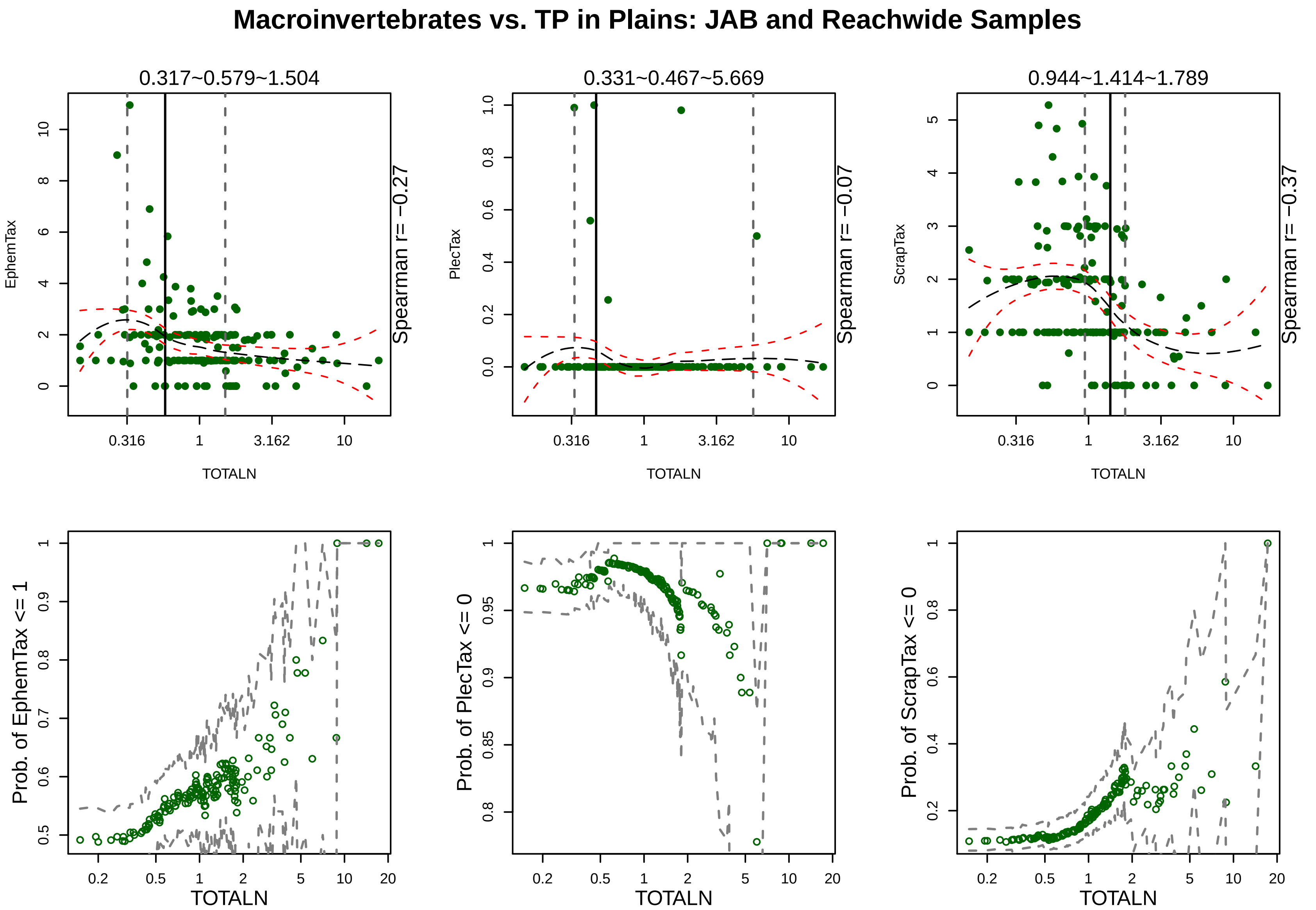


0007131

Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples



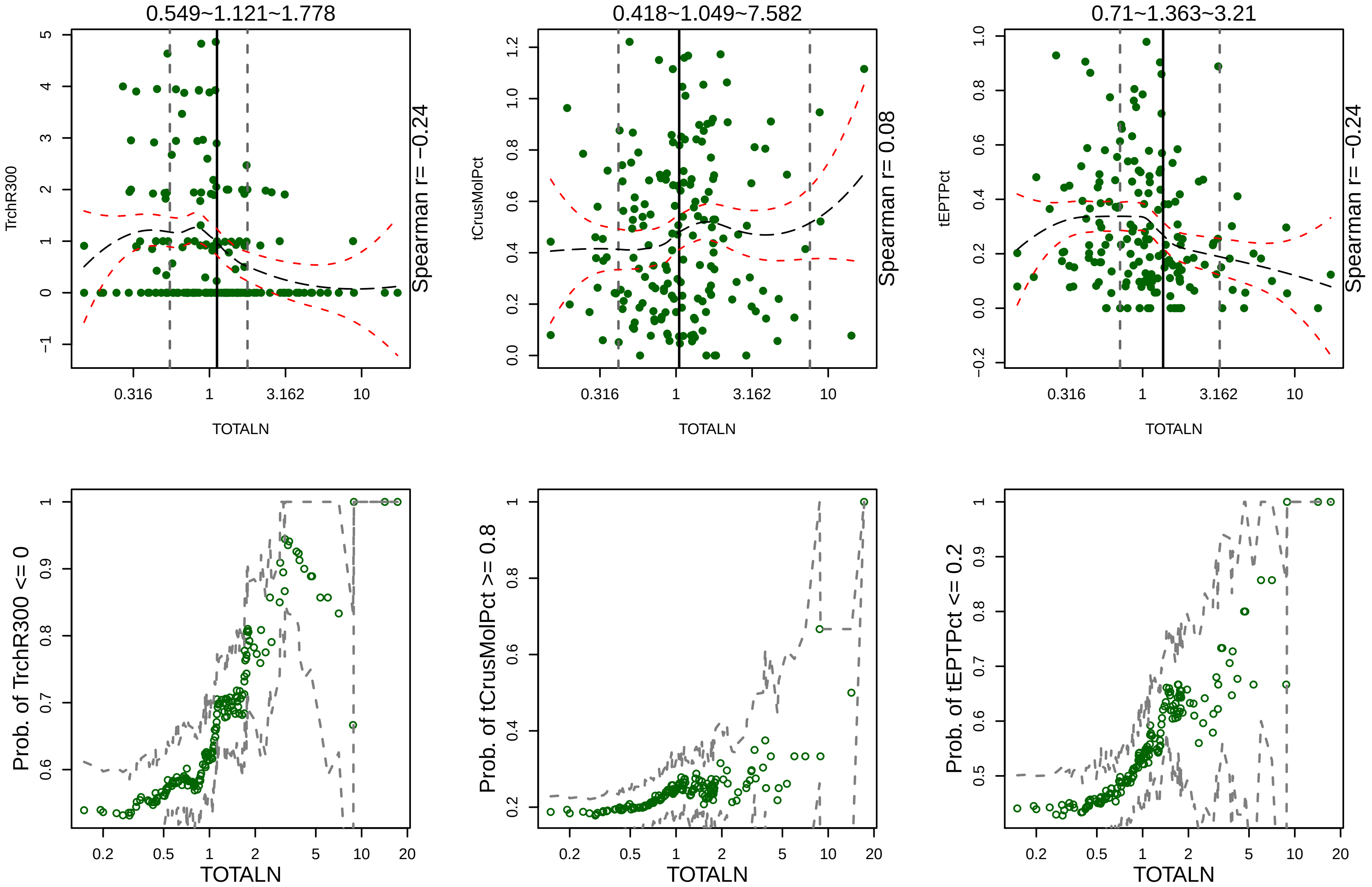
0007132



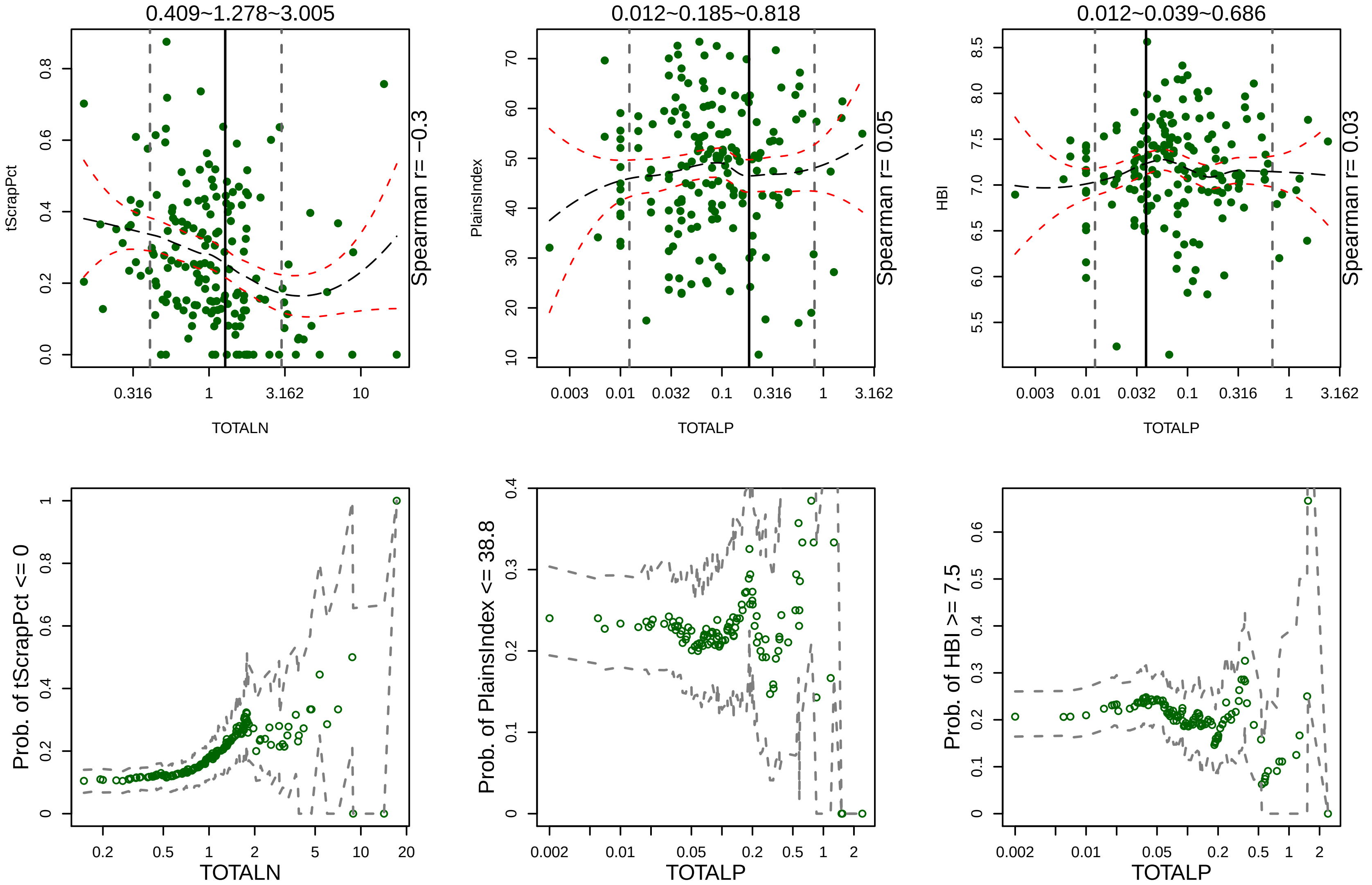
Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples
0.317~0.579~1.504
EphemTax
Spearman r= −0.27
TOTALN
0.331~0.467~5.669
PlecTax
Spearman r= −0.07
TOTALN
0.944~1.414~1.789
ScrapTax
Spearman r= −0.37
TOTALN
Prob. of EphemTax <= 1
TOTALN
Prob. of PlecTax <= 0
TOTALN
Prob. of ScrapTax <= 0
TOTALN

0007133

Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples

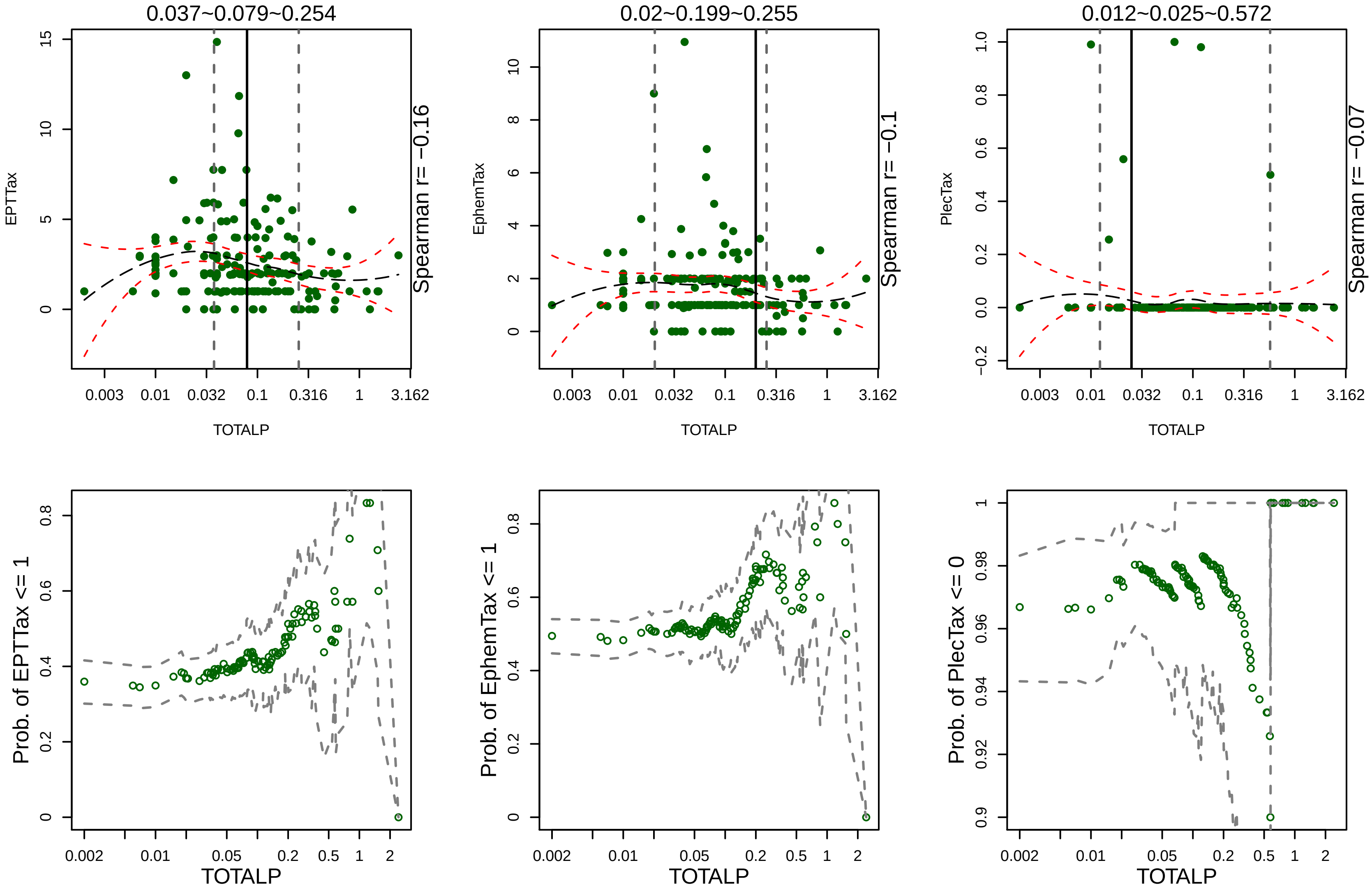


Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples



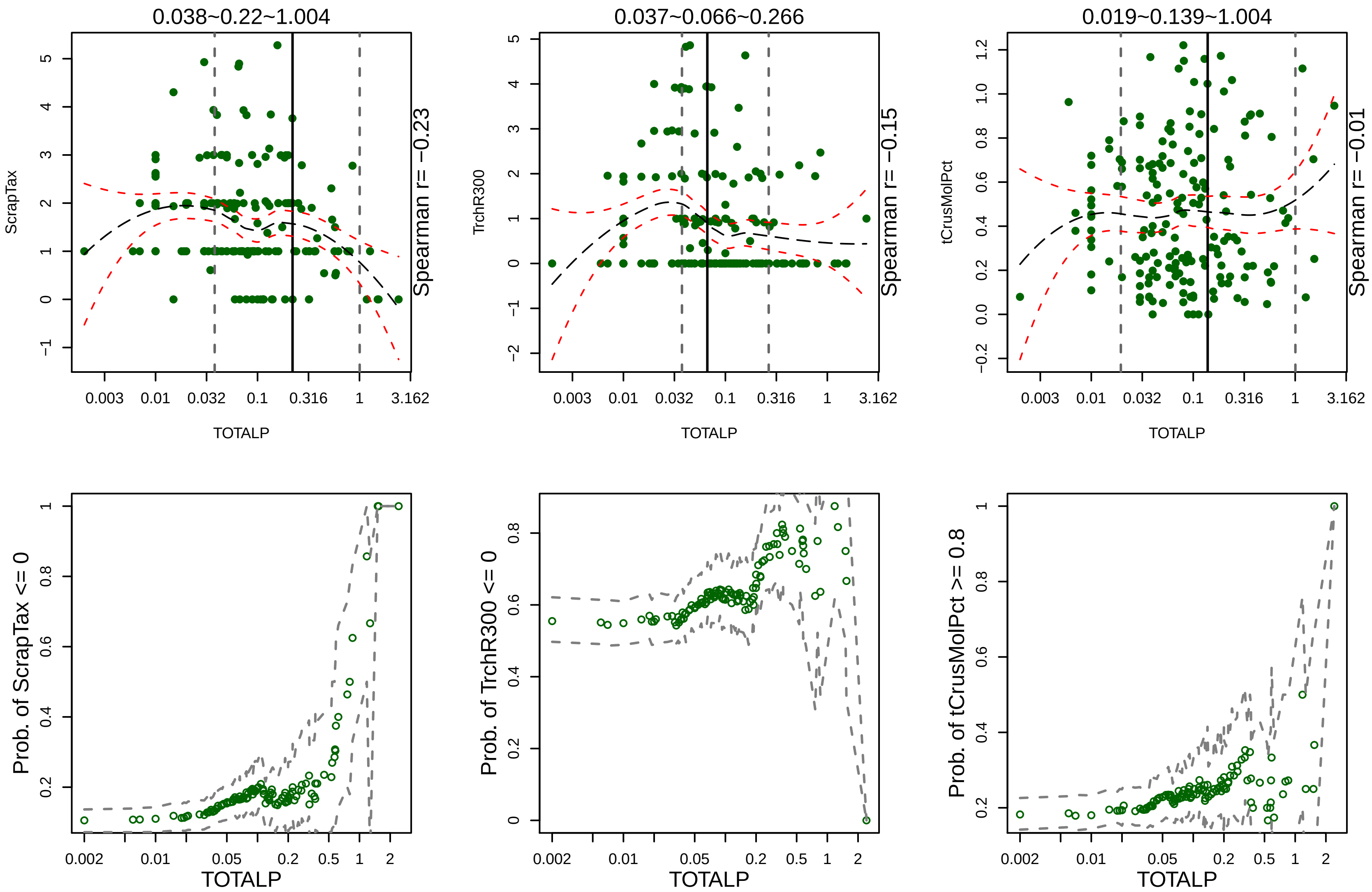
0007135

Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples

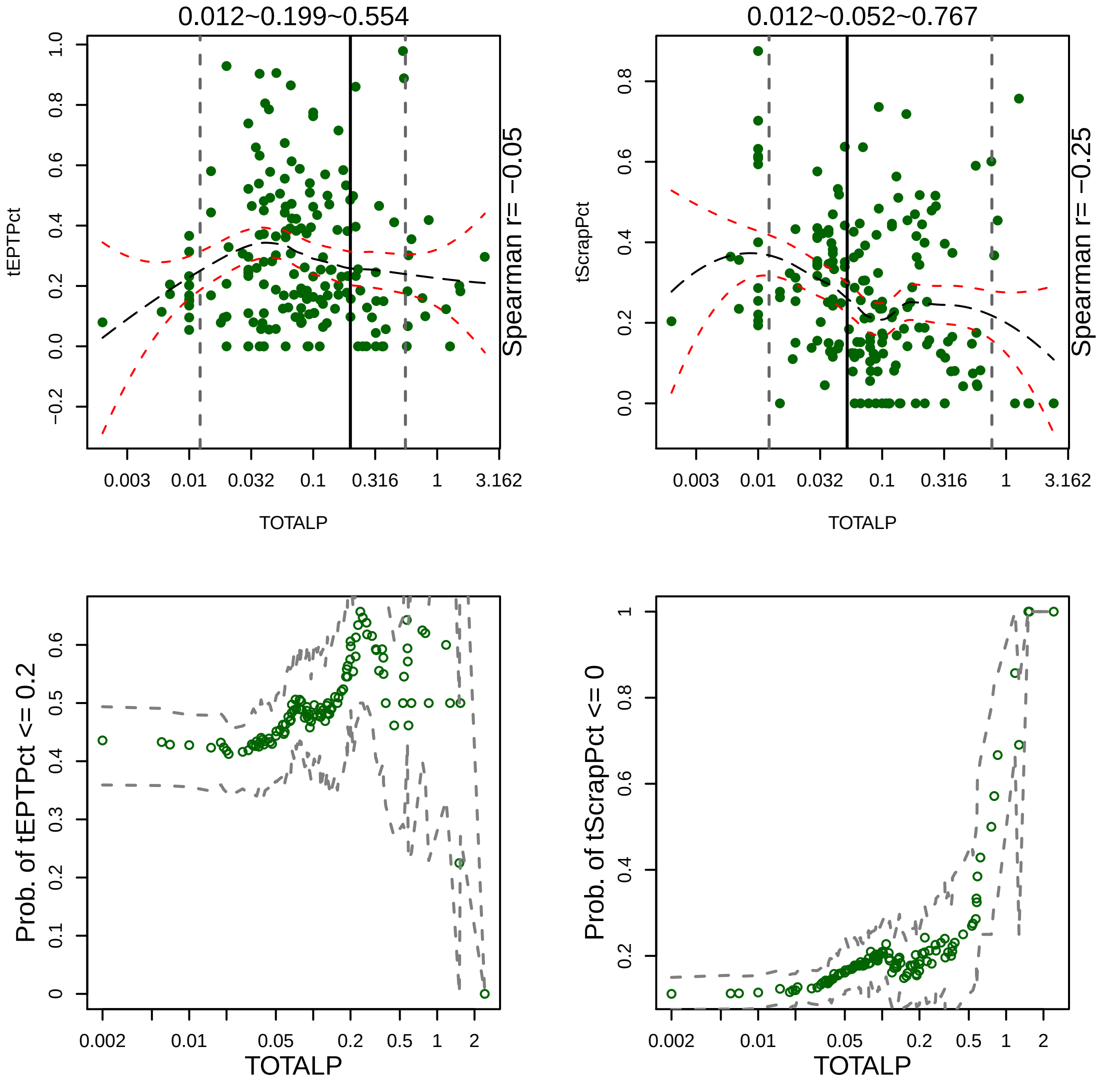


0007136

Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples



Macroinvertebrates vs. TP in Plains: JAB and Reachwide Samples



0007138

Appendix C

Benthic change-point analysis

Table C-1. Statistics from benthic macroinvertebrate change-point analysis.

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Great Plains	Kick_Riff	TN	MtnIndex	0.204	0.562	0.954	0
NW Great Plains	Kick_Riff	TN	LowValIndex	0.202	0.395	0.782	0.002
NW Great Plains	Kick_Riff	TN	PlainsIndex	0.183	0.627	1.888	0.001
NW Great Plains	Kick_Riff	TN	HBI	0.252	0.619	0.992	0
NW Great Plains	Kick_Riff	TN	ShredderTax	0.236	0.28	0.762	0
NW Great Plains	Kick_Riff	TN	EPTTax	0.237	0.616	1.289	0
NW Great Plains	Kick_Riff	TN	EphemTax	0.195	0.616	1.002	0
NW Great Plains	Kick_Riff	TN	PlecTax	0.232	0.252	0.382	0
NW Great Plains	Kick_Riff	TN	PredatorTax	0.177	0.371	1.97	0.019
NW Great Plains	Kick_Riff	TN	CllctTax	0.249	0.954	1.878	0.006
NW Great Plains	Kick_Riff	TN	FiltrTax	0.124	1.31	1.878	0.003
NW Great Plains	Kick_Riff	TN	PredTax	0.177	0.371	2.135	0.023
NW Great Plains	Kick_Riff	TN	ScrapTax	0.237	0.619	1.374	0
NW Great Plains	Kick_Riff	TN	ShredTax	0.236	0.28	0.764	0
NW Great Plains	Kick_Riff	TN	TrchR300	0.257	0.619	1.319	0
NW Great Plains	Kick_Riff	TN	tNonInsPct	0.338	0.787	1.289	0
NW Great Plains	Kick_Riff	TN	tCrusMolPct	0.237	0.795	1.414	0
NW Great Plains	Kick_Riff	TN	tFiltCollPct	0.252	0.353	1.289	0.001
NW Great Plains	Kick_Riff	TN	tEPTPct	0.616	0.839	1.034	0
NW Great Plains	Kick_Riff	TN	tPredPctM	0.265	0.895	1.622	0.003
NW Great Plains	Kick_Riff	TN	tEPTnoHBPct	0.232	0.619	0.954	0
NW Great Plains	Kick_Riff	TN	tMidgePct	0.269	0.847	1.888	0.018
NW Great Plains	Kick_Riff	TN	tPredPctLV	0.265	0.879	1.878	0.003
NW Great Plains	Kick_Riff	TN	tCllctPct	0.346	1.074	1.97	0
NW Great Plains	Kick_Riff	TN	tFiltrPct	0.146	0.616	1.549	0.009
NW Great Plains	Kick_Riff	TN	tPredPct	0.263	0.895	1.87	0.003
NW Great Plains	Kick_Riff	TN	tScrapPct	0.262	0.268	0.423	0
NW Glaciated Plns	Kick_Riff	TN	MtnIndex	0.139	0.342	1.205	0
NW Glaciated Plns	Kick_Riff	TN	LowValIndex	0.366	0.7	1.985	0.015
NW Glaciated Plns	Kick_Riff	TN	HBI	0.182	0.212	1.472	0
NW Glaciated Plns	Kick_Riff	TN	ShredderTax	0.137	0.182	0.944	0
NW Glaciated Plns	Kick_Riff	TN	EPTTax	0.139	0.342	2.018	0.004
NW Glaciated Plns	Kick_Riff	TN	EphemTax	0.304	0.457	2.211	0.005

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Glaciated Plns	Kick_Riff	TN	PlecTax	0.137	0.152	0.342	0
NW Glaciated Plns	Kick_Riff	TN	PredatorTax	0.081	0.472	2.037	0.002
NW Glaciated Plns	Kick_Riff	TN	CllctTax	0.172	0.488	0.829	0.003
NW Glaciated Plns	Kick_Riff	TN	PredTax	0.075	0.466	1.949	0.002
NW Glaciated Plns	Kick_Riff	TN	ShredTax	0.137	0.175	0.522	0
NW Glaciated Plns	Kick_Riff	TN	tTanypodPct	0.16	0.197	2.736	0.009
NW Glaciated Plns	Kick_Riff	TN	tNonInsPct	0.152	1.205	2.401	0.007
NW Glaciated Plns	Kick_Riff	TN	tCrusMolPct	0.437	1.007	2.401	0.007
NW Glaciated Plns	Kick_Riff	TN	tOrth2MidgPct	0.178	0.995	1.908	0.016
NW Glaciated Plns	Kick_Riff	TN	tFiltCollPct	0.115	0.566	1.205	0.006
NW Glaciated Plns	Kick_Riff	TN	tEPTPct	0.152	0.401	2.401	0.007
NW Glaciated Plns	Kick_Riff	TN	tPredPctM	0.075	0.537	2.248	0.028
NW Glaciated Plns	Kick_Riff	TN	tEPTnoHBPct	0.166	0.214	0.716	0
NW Glaciated Plns	Kick_Riff	TN	tShredPct	0.137	0.152	2.587	0
NW Glaciated Plns	Kick_Riff	TN	tPredPctLV	0.075	0.536	2.248	0.028
NW Glaciated Plns	Kick_Riff	TN	tPredPct	0.075	0.536	1.908	0.028
NW Glaciated Plns	Kick_Riff	TN	tScrapPct	0.488	1.136	1.705	0.003
Northern Rockies	Kick_Riff	TN	MtnIndex	0.042	0.17	0.792	0.013
Northern Rockies	Kick_Riff	TN	LowValIndex	0.016	0.316	0.792	0.001
Northern Rockies	Kick_Riff	TN	ShredderTax	0.043	0.107	0.192	0.01
Northern Rockies	Kick_Riff	TN	EPTTax	0.041	0.102	0.326	0.038
Northern Rockies	Kick_Riff	TN	PlecTax	0.085	0.187	0.265	0.015
Northern Rockies	Kick_Riff	TN	ScrapTax	0.042	0.102	0.455	0.034
Northern Rockies	Kick_Riff	TN	ShredTax	0.032	0.107	0.192	0.01
Northern Rockies	Kick_Riff	TN	tCrusMolPct	0.092	0.455	0.77	0
Northern Rockies	Kick_Riff	TN	O.E_p.half	0.062	0.095	0.154	0.023
Middle Rockies	Kick_Riff	TN	MtnIndex	0.127	0.347	0.67	0
Middle Rockies	Kick_Riff	TN	LowValIndex	0.19	0.392	1.202	0
Middle Rockies	Kick_Riff	TN	PlainsIndex	0.138	0.248	1.127	0
Middle Rockies	Kick_Riff	TN	HBI	0.127	0.495	0.905	0
Middle Rockies	Kick_Riff	TN	ShredderTax	0.099	0.242	1.127	0.042
Middle Rockies	Kick_Riff	TN	EPTTax	0.127	0.347	0.672	0
Middle Rockies	Kick_Riff	TN	EphemTax	0.122	0.347	0.665	0
Middle Rockies	Kick_Riff	TN	PlecTax	0.162	0.347	1.127	0
Middle Rockies	Kick_Riff	TN	PredatorTax	0.058	0.248	1.072	0.001
Middle Rockies	Kick_Riff	TN	PredTax	0.057	0.265	1.072	0.001
Middle Rockies	Kick_Riff	TN	ScrapTax	0.054	0.649	0.849	0.007
Middle Rockies	Kick_Riff	TN	ShredTax	0.057	0.24	1.127	0.04
Middle Rockies	Kick_Riff	TN	TrchR300	0.107	0.505	0.849	0.025
Middle Rockies	Kick_Riff	TN	tTanypodPct	0.055	0.287	0.83	0.024
Middle Rockies	Kick_Riff	TN	tNonInsPct	0.287	0.502	1.177	0

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Middle Rockies	Kick_Riff	TN	tCrusMolPct	0.269	0.535	1.202	0
Middle Rockies	Kick_Riff	TN	tFiltCollPct	0.089	0.245	0.954	0.003
Middle Rockies	Kick_Riff	TN	tEPTPct	0.065	0.275	0.504	0.004
Middle Rockies	Kick_Riff	TN	tEPTnoHBPct	0.107	0.276	0.61	0
Middle Rockies	Kick_Riff	TN	tShredPct	0.057	0.217	0.248	0
Middle Rockies	Kick_Riff	TN	tCllctPct	0.055	0.137	1.478	0.047
Middle Rockies	Kick_Riff	TN	tScrapPct	0.057	0.66	1.453	0.018
NW Great Plains	JAB_Reach	TN	HBI	0.309	0.531	3.238	0.038
NW Great Plains	JAB_Reach	TN	EPTTax	0.332	0.469	1.252	0.001
NW Great Plains	JAB_Reach	TN	EphemTax	0.32	0.447	1.138	0
NW Great Plains	JAB_Reach	TN	PlecTax	0.32	0.429	1.799	0.014
NW Great Plains	JAB_Reach	TN	CllctTax	0.463	0.705	1.578	0
NW Great Plains	JAB_Reach	TN	FiltrTax	0.361	1.166	3.311	0.011
NW Great Plains	JAB_Reach	TN	ScrapTax	0.529	1.121	1.708	0
NW Great Plains	JAB_Reach	TN	TrchR300	0.33	1.116	1.708	0.003
NW Great Plains	JAB_Reach	TN	tOrth2MidgPct	0.342	0.542	3.311	0.034
NW Great Plains	JAB_Reach	TN	tFiltCollPct	0.305	1.352	3.591	0.027
NW Great Plains	JAB_Reach	TN	tEPTPct	0.466	1.414	3.238	0.008
NW Great Plains	JAB_Reach	TN	tPredPctM	0.374	1.257	2.463	0.008
NW Great Plains	JAB_Reach	TN	tEPTnoHBPct	0.439	1.442	3.225	0.022
NW Great Plains	JAB_Reach	TN	tMidgePct	0.317	0.729	4.235	0.034
NW Great Plains	JAB_Reach	TN	tPredPctLV	0.305	1.247	2.395	0.008
NW Great Plains	JAB_Reach	TN	tPredPct	0.301	1.247	2.584	0.007
NW Great Plains	JAB_Reach	TN	tScrapPct	0.342	1.105	2.301	0.009
NW Great Plains	JAB_Reach	TN	O.E_p.half	0.948	1.71	1.772	0.001
NW Glaciated Plns	JAB_Reach	TN	MtnIndex	0.439	0.905	1.424	0.002
NW Glaciated Plns	JAB_Reach	TN	LowValIndex	0.903	1.335	1.408	0.004
NW Glaciated Plns	JAB_Reach	TN	HBI	0.422	0.811	4.286	0.004
NW Glaciated Plns	JAB_Reach	TN	EPTTax	0.479	0.87	1.361	0.001
NW Glaciated Plns	JAB_Reach	TN	EphemTax	0.474	0.69	1.451	0
NW Glaciated Plns	JAB_Reach	TN	ScrapTax	0.947	1.496	1.947	0.003
NW Glaciated Plns	JAB_Reach	TN	TrchR300	0.513	1.045	3.415	0.013
NW Glaciated Plns	JAB_Reach	TN	tOrth2MidgPct	0.513	2.839	3.494	0.009
NW Glaciated Plns	JAB_Reach	TN	tEPTPct	0.522	1.345	1.672	0.035
NW Glaciated Plns	JAB_Reach	TN	tEPTnoHBPct	0.583	1.35	1.928	0.032
NW Glaciated Plns	JAB_Reach	TN	tMidgePct	0.765	1.121	4.051	0.016
NW Glaciated Plns	JAB_Reach	TN	tShredPct	0.755	2.834	4.743	0.001
NW Glaciated Plns	JAB_Reach	TN	tScrapPct	0.53	1.799	3.415	0.011
NW Glaciated Plns	JAB_Reach	TN	O.E_p.half	0.69	1.238	3.091	0.022
NW Great Plains	Kick_Riff	TN	tTanypodPct	0.056	0.386	1.407	0.054
NW Great Plains	Kick_Riff	TN	tOrth2MidgPct	0.058	0.435	1.372	0.059

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Great Plains	Kick_Riff	TN	tShredPct	0.252	0.456	1.792	0.071
NW Great Plains	Kick_Riff	TN	O.E_p.half	0.105	0.315	1.298	0.308
NW Glaciated Plns	Kick_Riff	TN	PlainsIndex	0.134	0.472	1.846	0.128
NW Glaciated Plns	Kick_Riff	TN	FiltrTax	0.12	1.144	2.428	0.202
NW Glaciated Plns	Kick_Riff	TN	ScrapTax	0.115	1.002	2.13	0.067
NW Glaciated Plns	Kick_Riff	TN	TrchR300	0.122	1.092	2.156	0.107
NW Glaciated Plns	Kick_Riff	TN	tMidgePct	0.075	0.345	1.67	0.108
NW Glaciated Plns	Kick_Riff	TN	tCllctPct	0.075	0.659	2.018	0.204
NW Glaciated Plns	Kick_Riff	TN	tFiltrPct	0.075	0.974	2.617	0.27
NW Glaciated Plns	Kick_Riff	TN	O.E_p.half	0.172	1.291	1.512	0.074
Northern Rockies	Kick_Riff	TN	PlainsIndex	0.025	0.102	0.792	0.161
Northern Rockies	Kick_Riff	TN	HBI	0.057	0.17	0.792	0.056
Northern Rockies	Kick_Riff	TN	EphemTax	0.041	0.241	0.612	0.156
Northern Rockies	Kick_Riff	TN	PredatorTax	0.031	0.097	0.792	0.148
Northern Rockies	Kick_Riff	TN	CllctTax	0.042	0.089	0.455	0.197
Northern Rockies	Kick_Riff	TN	FiltrTax	0.011	0.065	0.63	0.221
Northern Rockies	Kick_Riff	TN	PredTax	0.031	0.095	0.792	0.148
Northern Rockies	Kick_Riff	TN	TrchR300	0.041	0.102	0.399	0.053
Northern Rockies	Kick_Riff	TN	tTanypodPct	0.025	0.192	0.63	0.317
Northern Rockies	Kick_Riff	TN	tNonInsPct	0.04	0.455	0.775	0.074
Northern Rockies	Kick_Riff	TN	tOrth2MidgPct	0.025	0.102	0.792	0.203
Northern Rockies	Kick_Riff	TN	tFiltCollPct	0.049	0.128	0.581	0.572
Northern Rockies	Kick_Riff	TN	tEPTPct	0.057	0.192	0.63	0.194
Northern Rockies	Kick_Riff	TN	tPredPctM	0.015	0.067	0.626	0.113
Northern Rockies	Kick_Riff	TN	tEPTnoHBPct	0.049	0.351	0.63	0.092
Northern Rockies	Kick_Riff	TN	tMidgePct	0.057	0.102	0.503	0.175
Northern Rockies	Kick_Riff	TN	tShredPct	0.032	0.212	0.612	0.174
Northern Rockies	Kick_Riff	TN	tPredPctLV	0.015	0.085	0.622	0.113
Northern Rockies	Kick_Riff	TN	tCllctPct	0.057	0.241	0.503	0.247
Northern Rockies	Kick_Riff	TN	tFiltrPct	0.057	0.059	0.455	0.09
Northern Rockies	Kick_Riff	TN	tPredPct	0.015	0.075	0.622	0.113
Northern Rockies	Kick_Riff	TN	tScrapPct	0.027	0.086	0.485	0.228
Middle Rockies	Kick_Riff	TN	CllctTax	0.054	0.232	1.152	0.051
Middle Rockies	Kick_Riff	TN	FiltrTax	0.052	0.255	2.354	0.306
Middle Rockies	Kick_Riff	TN	tOrth2MidgPct	0.054	0.344	1.807	0.173
Middle Rockies	Kick_Riff	TN	tPredPctM	0.054	0.286	2.049	0.064
Middle Rockies	Kick_Riff	TN	tMidgePct	0.058	0.547	1.96	0.235
Middle Rockies	Kick_Riff	TN	tPredPctLV	0.055	0.265	1.985	0.064
Middle Rockies	Kick_Riff	TN	tFiltrPct	0.055	0.255	1.795	0.121
Middle Rockies	Kick_Riff	TN	tPredPct	0.054	0.248	1.769	0.059
Middle Rockies	Kick_Riff	TN	O.E_p.half	0.056	0.225	1.641	0.092

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Great Plains	JAB_Reach	TN	MtnIndex	0.272	0.642	2.337	0.22
NW Great Plains	JAB_Reach	TN	LowValIndex	0.269	1.105	2.337	0.461
NW Great Plains	JAB_Reach	TN	PlainsIndex	0.269	0.947	3.311	0.222
NW Great Plains	JAB_Reach	TN	ShredderTax	0.342	0.531	2.419	0.071
NW Great Plains	JAB_Reach	TN	PredatorTax	0.297	0.947	4.273	0.094
NW Great Plains	JAB_Reach	TN	PredTax	0.297	0.672	4.273	0.098
NW Great Plains	JAB_Reach	TN	ShredTax	0.342	0.441	2.419	0.071
NW Great Plains	JAB_Reach	TN	tTanypodPct	0.302	1.029	4.235	0.124
NW Great Plains	JAB_Reach	TN	tNonInsPct	0.302	1.594	4.235	0.356
NW Great Plains	JAB_Reach	TN	tCrusMolPct	0.269	1.067	4.235	0.54
NW Great Plains	JAB_Reach	TN	tShredPct	0.342	1.029	2.674	0.19
NW Great Plains	JAB_Reach	TN	tCllctPct	0.298	1.398	3.591	0.204
NW Great Plains	JAB_Reach	TN	tFiltrPct	0.298	0.802	3.181	0.159
NW Glaciated Plns	JAB_Reach	TN	PlainsIndex	0.479	1.117	3.415	0.188
NW Glaciated Plns	JAB_Reach	TN	ShredderTax	0.513	1.087	3.021	0.169
NW Glaciated Plns	JAB_Reach	TN	PlecTax	0.479	0.583	4.743	0.064
NW Glaciated Plns	JAB_Reach	TN	PredatorTax	0.708	1.496	4.743	0.063
NW Glaciated Plns	JAB_Reach	TN	CllctTax	0.452	0.716	3.494	0.076
NW Glaciated Plns	JAB_Reach	TN	FiltrTax	0.513	0.708	2.834	0.056
NW Glaciated Plns	JAB_Reach	TN	PredTax	0.716	1.496	4.743	0.063
NW Glaciated Plns	JAB_Reach	TN	ShredTax	0.513	1.099	3.021	0.169
NW Glaciated Plns	JAB_Reach	TN	tTanypodPct	0.422	1.117	4.051	0.12
NW Glaciated Plns	JAB_Reach	TN	tNonInsPct	0.479	1.335	4.051	0.069
NW Glaciated Plns	JAB_Reach	TN	tCrusMolPct	0.436	1.117	4.051	0.092
NW Glaciated Plns	JAB_Reach	TN	tFiltCollPct	0.522	1.45	3.494	0.155
NW Glaciated Plns	JAB_Reach	TN	tPredPctM	0.447	1.316	4.007	0.299
NW Glaciated Plns	JAB_Reach	TN	tPredPctLV	0.474	1.406	4.007	0.299
NW Glaciated Plns	JAB_Reach	TN	tCllctPct	0.522	1.297	3.415	0.227
NW Glaciated Plns	JAB_Reach	TN	tFiltrPct	0.518	1.121	4.051	0.116
NW Glaciated Plns	JAB_Reach	TN	tPredPct	0.474	1.34	3.415	0.299
NW Great Plains	Kick_Riff	TP	MtnIndex	0.002	0.019	0.071	0
NW Great Plains	Kick_Riff	TP	LowValIndex	0.003	0.011	0.27	0.038
NW Great Plains	Kick_Riff	TP	PlainsIndex	0.002	0.004	0.183	0.017
NW Great Plains	Kick_Riff	TP	HBI	0.003	0.022	0.145	0
NW Great Plains	Kick_Riff	TP	ShredderTax	0.003	0.006	0.022	0.001
NW Great Plains	Kick_Riff	TP	EPTTax	0.003	0.022	0.111	0
NW Great Plains	Kick_Riff	TP	EphemTax	0.003	0.022	0.145	0.002
NW Great Plains	Kick_Riff	TP	PlecTax	0.002	0.02	0.045	0
NW Great Plains	Kick_Riff	TP	PredatorTax	0.002	0.019	0.056	0.022
NW Great Plains	Kick_Riff	TP	CllctTax	0.004	0.101	0.312	0.015
NW Great Plains	Kick_Riff	TP	FiltrTax	0.021	0.082	0.145	0.002

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Great Plains	Kick_Riff	TP	PredTax	0.002	0.024	0.056	0.021
NW Great Plains	Kick_Riff	TP	ScrapTax	0.002	0.021	0.101	0
NW Great Plains	Kick_Riff	TP	ShredTax	0.002	0.006	0.031	0.001
NW Great Plains	Kick_Riff	TP	TrchR300	0.004	0.022	0.13	0.001
NW Great Plains	Kick_Riff	TP	tTanypodPct	0.002	0.079	0.27	0.05
NW Great Plains	Kick_Riff	TP	tNonInsPct	0.005	0.026	0.243	0.029
NW Great Plains	Kick_Riff	TP	tCrusMolPct	0.005	0.023	0.056	0.024
NW Great Plains	Kick_Riff	TP	tOrth2MidgPct	0.013	0.04	0.27	0.022
NW Great Plains	Kick_Riff	TP	tEPTPct	0.003	0.056	0.166	0.037
NW Great Plains	Kick_Riff	TP	tPredPctM	0.005	0.111	0.27	0.014
NW Great Plains	Kick_Riff	TP	tEPTnoHBPct	0.002	0.004	0.116	0.007
NW Great Plains	Kick_Riff	TP	tPredPctLV	0.005	0.111	0.27	0.014
NW Great Plains	Kick_Riff	TP	tPredPct	0.005	0.111	0.27	0.014
NW Great Plains	Kick_Riff	TP	tScrapPct	0.009	0.022	0.222	0.001
NW Glaciated Plns	Kick_Riff	TP	MtnIndex	0.004	0.045	0.055	0
NW Glaciated Plns	Kick_Riff	TP	HBI	0.006	0.007	0.051	0
NW Glaciated Plns	Kick_Riff	TP	ShredderTax	0.003	0.007	0.148	0.007
NW Glaciated Plns	Kick_Riff	TP	EPTTax	0.004	0.051	0.078	0.001
NW Glaciated Plns	Kick_Riff	TP	EphemTax	0.009	0.051	0.101	0.001
NW Glaciated Plns	Kick_Riff	TP	PlecTax	0.003	0.007	0.052	0
NW Glaciated Plns	Kick_Riff	TP	ScrapTax	0.003	0.051	0.173	0.033
NW Glaciated Plns	Kick_Riff	TP	ShredTax	0.003	0.007	0.15	0.006
NW Glaciated Plns	Kick_Riff	TP	tTanypodPct	0.006	0.022	0.277	0.027
NW Glaciated Plns	Kick_Riff	TP	tNonInsPct	0.006	0.051	0.148	0.022
NW Glaciated Plns	Kick_Riff	TP	tFiltCollPct	0.006	0.046	0.257	0.028
NW Glaciated Plns	Kick_Riff	TP	tEPTPct	0.007	0.025	0.13	0.003
NW Glaciated Plns	Kick_Riff	TP	tEPTnoHBPct	0.007	0.02	0.052	0
NW Glaciated Plns	Kick_Riff	TP	tShredPct	0.003	0.007	0.229	0.015
Northern Rockies	Kick_Riff	TP	MtnIndex	0.003	0.008	0.03	0.001
Northern Rockies	Kick_Riff	TP	LowValIndex	0.001	0.028	0.042	0.038
Northern Rockies	Kick_Riff	TP	HBI	0.002	0.008	0.03	0.004
Northern Rockies	Kick_Riff	TP	EPTTax	0.003	0.007	0.042	0.003
Northern Rockies	Kick_Riff	TP	EphemTax	0.003	0.026	0.042	0.003
Northern Rockies	Kick_Riff	TP	PlecTax	0.003	0.007	0.009	0
Northern Rockies	Kick_Riff	TP	PredatorTax	0.003	0.009	0.042	0.028
Northern Rockies	Kick_Riff	TP	PredTax	0.003	0.009	0.042	0.031
Northern Rockies	Kick_Riff	TP	ScrapTax	0.003	0.007	0.041	0.013
Northern Rockies	Kick_Riff	TP	TrchR300	0.003	0.009	0.04	0.021
Northern Rockies	Kick_Riff	TP	tTanypodPct	0.003	0.009	0.035	0.036
Northern Rockies	Kick_Riff	TP	tCrusMolPct	0.006	0.016	0.039	0.003
Northern Rockies	Kick_Riff	TP	tEPTPct	0.002	0.007	0.028	0.004

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Northern Rockies	Kick_Riff	TP	tEPTnoHBPct	0.002	0.008	0.046	0.009
Northern Rockies	Kick_Riff	TP	tFiltrPct	0.002	0.006	0.01	0.015
Northern Rockies	Kick_Riff	TP	O.E_p.half	0.003	0.005	0.011	0.039
Middle Rockies	Kick_Riff	TP	MtnIndex	0.016	0.033	0.125	0
Middle Rockies	Kick_Riff	TP	LowValIndex	0.031	0.048	0.089	0
Middle Rockies	Kick_Riff	TP	PlainsIndex	0.004	0.036	0.494	0.001
Middle Rockies	Kick_Riff	TP	HBI	0.016	0.031	0.155	0
Middle Rockies	Kick_Riff	TP	ShredderTax	0.002	0.008	0.206	0.029
Middle Rockies	Kick_Riff	TP	EPTTax	0.007	0.084	0.155	0
Middle Rockies	Kick_Riff	TP	EphemTax	0.021	0.039	0.11	0
Middle Rockies	Kick_Riff	TP	PlecTax	0.007	0.046	0.155	0
Middle Rockies	Kick_Riff	TP	PredatorTax	0.004	0.007	0.11	0
Middle Rockies	Kick_Riff	TP	FiltrTax	0.001	0.025	0.28	0.037
Middle Rockies	Kick_Riff	TP	PredTax	0.006	0.006	0.15	0
Middle Rockies	Kick_Riff	TP	ScrapTax	0.007	0.084	0.187	0
Middle Rockies	Kick_Riff	TP	ShredTax	0.004	0.008	0.198	0.033
Middle Rockies	Kick_Riff	TP	TrchR300	0.005	0.084	0.19	0
Middle Rockies	Kick_Riff	TP	tTanypodPct	0.003	0.039	0.195	0.028
Middle Rockies	Kick_Riff	TP	tNonInsPct	0.038	0.047	0.24	0
Middle Rockies	Kick_Riff	TP	tCrusMolPct	0.027	0.046	0.17	0
Middle Rockies	Kick_Riff	TP	tFiltCollPct	0.004	0.009	0.404	0.007
Middle Rockies	Kick_Riff	TP	tEPTPct	0.008	0.027	0.031	0
Middle Rockies	Kick_Riff	TP	tEPTnoHBPct	0.008	0.032	0.097	0
Middle Rockies	Kick_Riff	TP	tMidgePct	0.014	0.056	0.084	0.011
Middle Rockies	Kick_Riff	TP	tShredPct	0.004	0.008	0.183	0.001
Middle Rockies	Kick_Riff	TP	tFiltrPct	0.004	0.018	0.544	0.03
Middle Rockies	Kick_Riff	TP	tScrapPct	0.008	0.136	0.28	0.014
Middle Rockies	Kick_Riff	TP	O.E_p.half	0.004	0.031	0.115	0.001
NW Great Plains	JAB_Reach	TP	EPTTax	0.034	0.047	0.225	0.013
NW Great Plains	JAB_Reach	TP	CllctTax	0.012	0.066	0.185	0.004
NW Great Plains	JAB_Reach	TP	TrchR300	0.037	0.047	0.209	0.015
NW Great Plains	JAB_Reach	TP	tOrth2MidgPct	0.012	0.05	0.293	0.042
NW Great Plains	JAB_Reach	TP	tMidgePct	0.012	0.033	0.341	0.014
NW Great Plains	JAB_Reach	TP	tShredPct	0.036	0.075	0.204	0.018
NW Great Plains	JAB_Reach	TP	tFiltrPct	0.008	0.084	0.35	0.026
NW Great Plains	JAB_Reach	TP	tScrapPct	0.012	0.046	0.321	0.026
NW Great Plains	JAB_Reach	TP	O.E_p.half	0.013	0.077	0.362	0.041
NW Glaciated Plns	JAB_Reach	TP	ShredderTax	0.024	0.086	1.004	0.047
NW Glaciated Plns	JAB_Reach	TP	EPTTax	0.024	0.068	0.294	0.011
NW Glaciated Plns	JAB_Reach	TP	EphemTax	0.024	0.184	0.297	0.028
NW Glaciated Plns	JAB_Reach	TP	PredatorTax	0.031	0.22	0.947	0.02

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Glaciated Plns	JAB_Reach	TP	CllctTax	0.024	0.331	0.407	0.011
NW Glaciated Plns	JAB_Reach	TP	PredTax	0.025	0.22	0.947	0.02
NW Glaciated Plns	JAB_Reach	TP	ScrapTax	0.043	0.22	0.947	0.009
NW Glaciated Plns	JAB_Reach	TP	ShredTax	0.024	0.068	1.004	0.047
NW Glaciated Plns	JAB_Reach	TP	TrchR300	0.024	0.068	0.406	0.015
NW Glaciated Plns	JAB_Reach	TP	tOrth2MidgPct	0.031	0.083	0.806	0.031
NW Glaciated Plns	JAB_Reach	TP	tFiltCollPct	0.051	0.076	1.004	0.043
NW Glaciated Plns	JAB_Reach	TP	tMidgePct	0.036	0.089	1.004	0.05
NW Glaciated Plns	JAB_Reach	TP	tShredPct	0.033	0.572	1.004	0
NW Glaciated Plns	JAB_Reach	TP	tScrapPct	0.032	0.053	1.004	0.004
NW Glaciated Plns	JAB_Reach	TP	O.E_p.half	0.067	0.257	0.621	0.015
NW Great Plains	Kick_Riff	TP	tFiltCollPct	0.002	0.009	0.169	0.076
NW Great Plains	Kick_Riff	TP	tMidgePct	0.004	0.02	0.131	0.22
NW Great Plains	Kick_Riff	TP	tShredPct	0.006	0.095	0.163	0.18
NW Great Plains	Kick_Riff	TP	tCllctPct	0.003	0.106	0.214	0.102
NW Great Plains	Kick_Riff	TP	tFiltrPct	0.004	0.02	0.117	0.063
NW Great Plains	Kick_Riff	TP	O.E_p.half	0.002	0.048	0.117	0.213
NW Glaciated Plns	Kick_Riff	TP	LowValIndex	0.001	0.038	0.214	0.185
NW Glaciated Plns	Kick_Riff	TP	PlainsIndex	0.004	0.051	0.257	0.119
NW Glaciated Plns	Kick_Riff	TP	PredatorTax	0.003	0.009	0.2	0.115
NW Glaciated Plns	Kick_Riff	TP	CllctTax	0.004	0.03	0.173	0.113
NW Glaciated Plns	Kick_Riff	TP	FiltrTax	0.004	0.051	0.156	0.375
NW Glaciated Plns	Kick_Riff	TP	PredTax	0.003	0.009	0.208	0.116
NW Glaciated Plns	Kick_Riff	TP	TrchR300	0.003	0.045	0.173	0.164
NW Glaciated Plns	Kick_Riff	TP	tCrusMolPct	0.007	0.051	0.173	0.183
NW Glaciated Plns	Kick_Riff	TP	tOrth2MidgPct	0.001	0.007	0.214	0.158
NW Glaciated Plns	Kick_Riff	TP	tPredPctM	0.007	0.035	0.257	0.171
NW Glaciated Plns	Kick_Riff	TP	tMidgePct	0.007	0.011	0.171	0.128
NW Glaciated Plns	Kick_Riff	TP	tPredPctLV	0.006	0.035	0.257	0.171
NW Glaciated Plns	Kick_Riff	TP	tCllctPct	0.007	0.033	0.214	0.333
NW Glaciated Plns	Kick_Riff	TP	tFiltrPct	0.007	0.101	0.218	0.222
NW Glaciated Plns	Kick_Riff	TP	tPredPct	0.007	0.035	0.257	0.17
NW Glaciated Plns	Kick_Riff	TP	tScrapPct	0.004	0.073	0.214	0.193
NW Glaciated Plns	Kick_Riff	TP	O.E_p.half	0.013	0.088	0.142	0.058
Northern Rockies	Kick_Riff	TP	PlainsIndex	0.002	0.007	0.03	0.248
Northern Rockies	Kick_Riff	TP	ShredderTax	0.003	0.009	0.04	0.258
Northern Rockies	Kick_Riff	TP	CllctTax	0.001	0.016	0.042	0.095
Northern Rockies	Kick_Riff	TP	FiltrTax	0.002	0.004	0.035	0.113
Northern Rockies	Kick_Riff	TP	ShredTax	0.003	0.009	0.035	0.258
Northern Rockies	Kick_Riff	TP	tNonInsPct	0.002	0.011	0.029	0.127
Northern Rockies	Kick_Riff	TP	tOrth2MidgPct	0.001	0.008	0.04	0.672

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Northern Rockies	Kick_Riff	TP	tFiltCollPct	0.002	0.007	0.042	0.286
Northern Rockies	Kick_Riff	TP	tPredPctM	0.001	0.002	0.028	0.062
Northern Rockies	Kick_Riff	TP	tMidgePct	0.002	0.007	0.029	0.074
Northern Rockies	Kick_Riff	TP	tShredPct	0.003	0.009	0.042	0.322
Northern Rockies	Kick_Riff	TP	tPredPctLV	0.001	0.002	0.028	0.062
Northern Rockies	Kick_Riff	TP	tCllctPct	0.002	0.008	0.042	0.257
Northern Rockies	Kick_Riff	TP	tPredPct	0.001	0.002	0.035	0.065
Northern Rockies	Kick_Riff	TP	tScrapPct	0.002	0.008	0.042	0.298
Middle Rockies	Kick_Riff	TP	CllctTax	0.001	0.031	0.25	0.115
Middle Rockies	Kick_Riff	TP	tOrth2MidgPct	0.001	0.053	0.349	0.364
Middle Rockies	Kick_Riff	TP	tPredPctM	0.004	0.031	0.261	0.126
Middle Rockies	Kick_Riff	TP	tPredPctLV	0.004	0.031	0.266	0.126
Middle Rockies	Kick_Riff	TP	tCllctPct	0.001	0.057	0.216	0.192
Middle Rockies	Kick_Riff	TP	tPredPct	0.004	0.031	0.185	0.125
NW Great Plains	JAB_Reach	TP	MtnIndex	0.019	0.08	0.312	0.247
NW Great Plains	JAB_Reach	TP	LowValIndex	0.019	0.075	0.293	0.194
NW Great Plains	JAB_Reach	TP	PlainsIndex	0.018	0.185	0.342	0.142
NW Great Plains	JAB_Reach	TP	HBI	0.012	0.075	0.153	0.189
NW Great Plains	JAB_Reach	TP	ShredderTax	0.017	0.075	0.35	0.16
NW Great Plains	JAB_Reach	TP	EphemTax	0.014	0.042	0.235	0.061
NW Great Plains	JAB_Reach	TP	PlecTax	0.012	0.024	0.117	0.066
NW Great Plains	JAB_Reach	TP	PredatorTax	0.008	0.079	0.321	0.385
NW Great Plains	JAB_Reach	TP	FiltrTax	0.02	0.124	0.372	0.378
NW Great Plains	JAB_Reach	TP	PredTax	0.008	0.079	0.33	0.391
NW Great Plains	JAB_Reach	TP	ScrapTax	0.012	0.075	0.295	0.054
NW Great Plains	JAB_Reach	TP	ShredTax	0.018	0.075	0.35	0.16
NW Great Plains	JAB_Reach	TP	tTanypodPct	0.012	0.088	0.394	0.205
NW Great Plains	JAB_Reach	TP	tNonInsPct	0.024	0.097	0.441	0.293
NW Great Plains	JAB_Reach	TP	tCrusMolPct	0.019	0.097	0.331	0.447
NW Great Plains	JAB_Reach	TP	tFiltCollPct	0.012	0.08	0.372	0.286
NW Great Plains	JAB_Reach	TP	tEPTPct	0.019	0.075	0.331	0.152
NW Great Plains	JAB_Reach	TP	tPredPctM	0.014	0.136	0.336	0.176
NW Great Plains	JAB_Reach	TP	tEPTnoHBPct	0.019	0.068	0.361	0.206
NW Great Plains	JAB_Reach	TP	tPredPctLV	0.015	0.092	0.295	0.176
NW Great Plains	JAB_Reach	TP	tCllctPct	0.012	0.084	0.372	0.239
NW Great Plains	JAB_Reach	TP	tPredPct	0.012	0.138	0.328	0.176
NW Glaciated Plns	JAB_Reach	TP	MtnIndex	0.024	0.159	0.549	0.371
NW Glaciated Plns	JAB_Reach	TP	LowValIndex	0.031	0.235	1.004	0.087
NW Glaciated Plns	JAB_Reach	TP	PlainsIndex	0.034	0.076	0.806	0.301
NW Glaciated Plns	JAB_Reach	TP	HBI	0.028	0.068	0.552	0.112
NW Glaciated Plns	JAB_Reach	TP	PlecTax	0.031	0.069	0.572	0.543

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
NW Glaciated Plns	JAB_Reach	TP	FiltrTax	0.024	0.084	0.664	0.195
NW Glaciated Plns	JAB_Reach	TP	tTanypodPct	0.031	0.442	1.004	0.324
NW Glaciated Plns	JAB_Reach	TP	tNonInsPct	0.031	0.191	0.766	0.583
NW Glaciated Plns	JAB_Reach	TP	tCrusMolPct	0.031	0.22	0.977	0.467
NW Glaciated Plns	JAB_Reach	TP	tEPTPct	0.024	0.179	0.552	0.138
NW Glaciated Plns	JAB_Reach	TP	tPredPctM	0.031	0.084	0.664	0.16
NW Glaciated Plns	JAB_Reach	TP	tEPTnoHBPct	0.042	0.262	0.554	0.174
NW Glaciated Plns	JAB_Reach	TP	tPredPctLV	0.031	0.084	0.664	0.16
NW Glaciated Plns	JAB_Reach	TP	tCllctPct	0.049	0.067	1.004	0.054
NW Glaciated Plns	JAB_Reach	TP	tFiltrPct	0.024	0.368	0.458	0.066
NW Glaciated Plns	JAB_Reach	TP	tPredPct	0.031	0.084	0.664	0.16
Lowvalley	KickOnly	TN	MtnIndex	0.177	0.347	0.391	0.001
Lowvalley	KickOnly	TN	LowValIndex	0.186	0.392	1.259	0.003
Lowvalley	KickOnly	TN	PlainsIndex	0.075	1.125	1.208	0.027
Lowvalley	KickOnly	TN	HBI	0.154	0.329	1.541	0.001
Lowvalley	KickOnly	TN	ShredderTax	0.075	0.495	1.127	0.41
Lowvalley	KickOnly	TN	EPTTax	0.186	0.347	1.126	0.007
Lowvalley	KickOnly	TN	EphemTax	0.138	0.286	0.419	0.004
Lowvalley	KickOnly	TN	PlecTax	0.075	0.347	1.208	0.023
Lowvalley	KickOnly	TN	PredatorTax	0.057	0.677	1.125	0.07
Lowvalley	KickOnly	TN	CllctTax	0.057	0.702	1.152	0.047
Lowvalley	KickOnly	TN	FiltrTax	0.057	0.265	1.859	0.408
Lowvalley	KickOnly	TN	PredTax	0.057	0.665	1.125	0.047
Lowvalley	KickOnly	TN	ScrapTax	0.057	0.547	1.911	0.043
Lowvalley	KickOnly	TN	ShredTax	0.075	0.495	1.127	0.41
Lowvalley	KickOnly	TN	TrchR300	0.057	0.222	1.102	0.133
Lowvalley	KickOnly	TN	tTanypodPct	0.057	0.287	0.551	0.07
Lowvalley	KickOnly	TN	tNonInsPct	0.177	0.366	2.049	0.005
Lowvalley	KickOnly	TN	tCrusMolPct	0.177	0.394	1.215	0.002
Lowvalley	KickOnly	TN	tOrth2MidgPct	0.057	0.422	1.295	0.128
Lowvalley	KickOnly	TN	tFiltCollPct	0.065	0.265	1.59	0.106
Lowvalley	KickOnly	TN	tEPTPct	0.057	0.329	1.859	0.295
Lowvalley	KickOnly	TN	tPredPctM	0.057	0.635	1.859	0.081
Lowvalley	KickOnly	TN	tEPTnoHBPct	0.124	0.276	0.699	0.003
Lowvalley	KickOnly	TN	tMidgePct	0.065	0.394	1.859	0.504
Lowvalley	KickOnly	TN	tShredPct	0.057	0.245	1.749	0.133
Lowvalley	KickOnly	TN	tPredPctLV	0.057	0.635	1.859	0.081
Lowvalley	KickOnly	TN	tCllctPct	0.057	0.326	2.049	0.407
Lowvalley	KickOnly	TN	tFiltrPct	0.061	0.275	1.879	0.155
Lowvalley	KickOnly	TN	tPredPct	0.057	0.635	1.859	0.081
Lowvalley	KickOnly	TN	tScrapPct	0.057	0.659	1.265	0.03

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Lowvalley	KickOnly	TN	O.E_p.half	0.122	0.695	1.479	0.13
Lowvalley	KickOnly	TP	MtnIndex	0.033	0.045	0.157	0
Lowvalley	KickOnly	TP	LowValIndex	0.038	0.048	0.085	0
Lowvalley	KickOnly	TP	PlainsIndex	0.003	0.051	0.169	0.002
Lowvalley	KickOnly	TP	HBI	0.017	0.042	0.224	0
Lowvalley	KickOnly	TP	ShredderTax	0.001	0.026	0.255	0.163
Lowvalley	KickOnly	TP	EPTTax	0.031	0.083	0.155	0
Lowvalley	KickOnly	TP	EphemTax	0.02	0.035	0.095	0
Lowvalley	KickOnly	TP	PlecTax	0.033	0.074	0.158	0
Lowvalley	KickOnly	TP	PredatorTax	0.003	0.079	0.155	0.035
Lowvalley	KickOnly	TP	CllctTax	0.001	0.024	0.404	0.207
Lowvalley	KickOnly	TP	FiltrTax	0.001	0.037	0.28	0.149
Lowvalley	KickOnly	TP	PredTax	0.003	0.084	0.155	0.04
Lowvalley	KickOnly	TP	ScrapTax	0.018	0.084	0.174	0
Lowvalley	KickOnly	TP	ShredTax	0.001	0.026	0.403	0.163
Lowvalley	KickOnly	TP	TrchR300	0.005	0.084	0.169	0.002
Lowvalley	KickOnly	TP	tTanypodPct	0.002	0.026	0.217	0.054
Lowvalley	KickOnly	TP	tNonInsPct	0.037	0.048	0.396	0
Lowvalley	KickOnly	TP	tCrusMolPct	0.034	0.051	0.28	0
Lowvalley	KickOnly	TP	tOrth2MidgPct	0.001	0.042	0.316	0.547
Lowvalley	KickOnly	TP	tFiltCollPct	0.001	0.048	0.588	0.069
Lowvalley	KickOnly	TP	tEPTPct	0.003	0.019	0.174	0
Lowvalley	KickOnly	TP	tPredPctM	0.003	0.074	0.195	0.185
Lowvalley	KickOnly	TP	tEPTnoHBPct	0.009	0.042	0.158	0
Lowvalley	KickOnly	TP	tMidgePct	0.009	0.054	0.171	0.098
Lowvalley	KickOnly	TP	tShredPct	0.001	0.108	0.41	0.41
Lowvalley	KickOnly	TP	tPredPctLV	0.002	0.064	0.2	0.185
Lowvalley	KickOnly	TP	tCllctPct	0.001	0.043	0.195	0.328
Lowvalley	KickOnly	TP	tFiltrPct	0.002	0.075	0.446	0.315
Lowvalley	KickOnly	TP	tPredPct	0.003	0.064	0.195	0.188
Lowvalley	KickOnly	TP	tScrapPct	0.002	0.083	0.28	0.239
Lowvalley	KickOnly	TP	O.E_p.half	0.019	0.084	0.115	0.002
Mountains	KickTarRiff	TN	MtnIndex	0.102	0.247	1.177	0
Mountains	KickTarRiff	TN	LowValIndex	0.211	1.054	1.225	0
Mountains	KickTarRiff	TN	PlainsIndex	0.052	0.207	1.054	0.002
Mountains	KickTarRiff	TN	HBI	0.102	0.48	1.154	0
Mountains	KickTarRiff	TN	ShredderTax	0.035	0.107	0.24	0.001
Mountains	KickTarRiff	TN	EPTTax	0.042	0.167	1.127	0
Mountains	KickTarRiff	TN	EphemTax	0.042	0.255	1.127	0.003
Mountains	KickTarRiff	TN	PlecTax	0.107	0.202	1.065	0
Mountains	KickTarRiff	TN	PredatorTax	0.04	0.102	0.684	0.004

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Mountains	KickTarRiff	TN	CllctTax	0.041	0.094	1.562	0.304
Mountains	KickTarRiff	TN	FiltrTax	0.04	0.347	0.607	0.041
Mountains	KickTarRiff	TN	PredTax	0.04	0.107	0.923	0.004
Mountains	KickTarRiff	TN	ScrapTax	0.04	0.134	1.054	0.036
Mountains	KickTarRiff	TN	ShredTax	0.04	0.167	0.24	0.001
Mountains	KickTarRiff	TN	TrchR300	0.032	0.115	1.075	0.009
Mountains	KickTarRiff	TN	tTanypodPct	0.056	0.255	1.225	0.009
Mountains	KickTarRiff	TN	tNonInsPct	0.211	0.464	1.225	0
Mountains	KickTarRiff	TN	tCrusMolPct	0.248	0.905	1.225	0
Mountains	KickTarRiff	TN	tOrth2MidgPct	0.025	0.312	0.992	0.255
Mountains	KickTarRiff	TN	tFiltCollPct	0.047	0.202	0.48	0.001
Mountains	KickTarRiff	TN	tEPTPct	0.102	0.207	0.481	0
Mountains	KickTarRiff	TN	tPredPctM	0.015	0.502	1.177	0.117
Mountains	KickTarRiff	TN	tEPTnoHBPct	0.102	0.237	1.054	0
Mountains	KickTarRiff	TN	tMidgePct	0.102	0.194	1.19	0.002
Mountains	KickTarRiff	TN	tShredPct	0.055	0.107	1.127	0.002
Mountains	KickTarRiff	TN	tPredPctLV	0.015	0.502	1.177	0.117
Mountains	KickTarRiff	TN	tCllctPct	0.055	0.202	0.992	0.02
Mountains	KickTarRiff	TN	tFiltrPct	0.055	0.147	0.645	0.05
Mountains	KickTarRiff	TN	tPredPct	0.015	0.502	1.177	0.117
Mountains	KickTarRiff	TN	tScrapPct	0.056	0.208	1.418	0.326
Mountains	KickTarRiff	TN	O.E_p.half	0.115	0.255	0.375	0
Mountains	KickTarRiff	TP	MtnIndex	0.008	0.018	0.031	0
Mountains	KickTarRiff	TP	LowValIndex	0.027	0.031	0.115	0
Mountains	KickTarRiff	TP	PlainsIndex	0.003	0.02	0.114	0.01
Mountains	KickTarRiff	TP	HBI	0.007	0.018	0.035	0
Mountains	KickTarRiff	TP	ShredderTax	0.005	0.008	0.034	0.001
Mountains	KickTarRiff	TP	EPTTax	0.007	0.017	0.032	0
Mountains	KickTarRiff	TP	EphemTax	0.007	0.027	0.043	0
Mountains	KickTarRiff	TP	PlecTax	0.007	0.008	0.018	0
Mountains	KickTarRiff	TP	PredatorTax	0.006	0.008	0.031	0
Mountains	KickTarRiff	TP	CllctTax	0.001	0.009	0.199	0.119
Mountains	KickTarRiff	TP	FiltrTax	0.001	0.005	0.17	0.07
Mountains	KickTarRiff	TP	PredTax	0.006	0.008	0.031	0
Mountains	KickTarRiff	TP	ScrapTax	0.007	0.018	0.044	0.002
Mountains	KickTarRiff	TP	ShredTax	0.005	0.008	0.031	0.001
Mountains	KickTarRiff	TP	TrchR300	0.007	0.018	0.042	0
Mountains	KickTarRiff	TP	tTanypodPct	0.004	0.009	0.104	0
Mountains	KickTarRiff	TP	tNonInsPct	0.008	0.045	0.159	0
Mountains	KickTarRiff	TP	tCrusMolPct	0.008	0.03	0.104	0
Mountains	KickTarRiff	TP	tOrth2MidgPct	0.001	0.015	0.15	0.011

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Mountains	KickTarRiff	TP	tFiltCollPct	0.003	0.009	0.031	0.001
Mountains	KickTarRiff	TP	tEPTPct	0.007	0.009	0.03	0
Mountains	KickTarRiff	TP	tPredPctM	0.001	0.02	0.133	0.286
Mountains	KickTarRiff	TP	tEPTnoHBPct	0.006	0.016	0.027	0
Mountains	KickTarRiff	TP	tMidgePct	0.002	0.007	0.17	0.03
Mountains	KickTarRiff	TP	tShredPct	0.004	0.009	0.057	0.011
Mountains	KickTarRiff	TP	tPredPctLV	0.001	0.021	0.15	0.286
Mountains	KickTarRiff	TP	tCllctPct	0.002	0.009	0.075	0.062
Mountains	KickTarRiff	TP	tFiltrPct	0.004	0.008	0.018	0.001
Mountains	KickTarRiff	TP	tPredPct	0.001	0.02	0.15	0.3
Mountains	KickTarRiff	TP	tScrapPct	0.001	0.058	0.133	0.02
Mountains	KickTarRiff	TP	O.E_p.half	0.005	0.012	0.102	0
Plains	KickTarRiff	TN	MtnIndex	0.252	0.636	0.806	0
Plains	KickTarRiff	TN	LowValIndex	0.289	0.396	1.195	0
Plains	KickTarRiff	TN	PlainsIndex	0.065	0.514	1.234	0.001
Plains	KickTarRiff	TN	HBI	0.252	0.619	0.839	0
Plains	KickTarRiff	TN	ShredderTax	0.235	0.448	0.725	0
Plains	KickTarRiff	TN	EPTTax	0.252	0.624	1.028	0
Plains	KickTarRiff	TN	EphemTax	0.336	0.631	1.289	0
Plains	KickTarRiff	TN	PlecTax	0.196	0.257	0.501	0
Plains	KickTarRiff	TN	PredatorTax	0.137	0.506	2.167	0.008
Plains	KickTarRiff	TN	CllctTax	0.501	0.625	1.21	0
Plains	KickTarRiff	TN	FiltrTax	0.124	1.415	2.415	0.006
Plains	KickTarRiff	TN	PredTax	0.169	0.501	1.766	0.009
Plains	KickTarRiff	TN	ScrapTax	0.235	0.387	1.828	0
Plains	KickTarRiff	TN	ShredTax	0.194	0.582	0.725	0
Plains	KickTarRiff	TN	TrchR300	0.266	0.624	1.784	0
Plains	KickTarRiff	TN	tTanypodPct	0.078	0.342	2.913	0.077
Plains	KickTarRiff	TN	tNonInsPct	0.357	0.971	2.054	0
Plains	KickTarRiff	TN	tCrusMolPct	0.585	0.971	2.054	0
Plains	KickTarRiff	TN	tOrth2MidgPct	0.196	0.707	1.89	0.003
Plains	KickTarRiff	TN	tFiltCollPct	0.252	0.524	1.074	0
Plains	KickTarRiff	TN	tEPTPct	0.557	0.824	1.784	0
Plains	KickTarRiff	TN	tPredPctM	0.065	0.979	2.585	0.081
Plains	KickTarRiff	TN	tEPTnoHBPct	0.342	0.624	0.813	0
Plains	KickTarRiff	TN	tMidgePct	0.065	0.302	2.585	0.098
Plains	KickTarRiff	TN	tShredPct	0.252	0.582	0.765	0
Plains	KickTarRiff	TN	tPredPctLV	0.065	0.979	2.323	0.081
Plains	KickTarRiff	TN	tCllctPct	0.291	1.256	2.401	0.005
Plains	KickTarRiff	TN	tFiltrPct	0.191	0.612	3.156	0.003
Plains	KickTarRiff	TN	tPredPct	0.078	0.982	2.557	0.081

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Plains	KickTarRiff	TN	tScrapPct	0.262	0.396	0.995	0
Plains	KickTarRiff	TN	O.E_p.half	0.078	0.501	1.397	0.378
Plains	KickTarRiff	TP	MtnIndex	0.003	0.051	0.056	0
Plains	KickTarRiff	TP	LowValIndex	0.003	0.024	0.369	0.033
Plains	KickTarRiff	TP	PlainsIndex	0.003	0.004	0.196	0.004
Plains	KickTarRiff	TP	HBI	0.008	0.022	0.145	0
Plains	KickTarRiff	TP	ShredderTax	0.003	0.008	0.077	0.003
Plains	KickTarRiff	TP	EPTTax	0.003	0.03	0.13	0
Plains	KickTarRiff	TP	EphemTax	0.003	0.051	0.145	0
Plains	KickTarRiff	TP	PlecTax	0.002	0.009	0.053	0
Plains	KickTarRiff	TP	PredatorTax	0.002	0.004	0.27	0.004
Plains	KickTarRiff	TP	CllctTax	0.003	0.082	0.274	0.011
Plains	KickTarRiff	TP	FiltrTax	0.007	0.078	0.326	0.016
Plains	KickTarRiff	TP	PredTax	0.002	0.004	0.295	0.005
Plains	KickTarRiff	TP	ScrapTax	0.003	0.022	0.147	0
Plains	KickTarRiff	TP	ShredTax	0.003	0.008	0.101	0.003
Plains	KickTarRiff	TP	TrchR300	0.003	0.03	0.164	0.004
Plains	KickTarRiff	TP	tTanypodPct	0.003	0.052	0.416	0.021
Plains	KickTarRiff	TP	tNonInsPct	0.009	0.051	0.175	0.001
Plains	KickTarRiff	TP	tCrusMolPct	0.007	0.03	0.25	0.027
Plains	KickTarRiff	TP	tOrth2MidgPct	0.008	0.077	0.268	0.045
Plains	KickTarRiff	TP	tFiltCollPct	0.003	0.02	0.263	0.006
Plains	KickTarRiff	TP	tEPTPct	0.029	0.051	0.145	0
Plains	KickTarRiff	TP	tPredPctM	0.018	0.257	0.297	0.006
Plains	KickTarRiff	TP	tEPTnoHBPct	0.003	0.031	0.116	0.002
Plains	KickTarRiff	TP	tMidgePct	0.005	0.059	0.369	0.472
Plains	KickTarRiff	TP	tShredPct	0.004	0.008	0.142	0.022
Plains	KickTarRiff	TP	tPredPctLV	0.007	0.257	0.285	0.006
Plains	KickTarRiff	TP	tCllctPct	0.004	0.111	0.369	0.12
Plains	KickTarRiff	TP	tFiltrPct	0.008	0.02	0.25	0.042
Plains	KickTarRiff	TP	tPredPct	0.032	0.257	0.286	0.006
Plains	KickTarRiff	TP	tScrapPct	0.009	0.022	0.214	0
Plains	KickTarRiff	TP	O.E_p.half	0.006	0.015	0.142	0.237
Plains	JAB&Reach	TN	MtnIndex	0.296	0.92	2.261	0.034
Plains	JAB&Reach	TN	LowValIndex	0.423	1.096	5.033	0.054
Plains	JAB&Reach	TN	PlainsIndex	0.257	0.947	3.602	0.122
Plains	JAB&Reach	TN	HBI	0.282	0.612	5.033	0.048
Plains	JAB&Reach	TN	ShredderTax	0.331	0.612	3.09	0.15
Plains	JAB&Reach	TN	EPTTax	0.331	0.92	1.35	0
Plains	JAB&Reach	TN	EphemTax	0.298	0.487	1.472	0
Plains	JAB&Reach	TN	PlecTax	0.331	0.467	5.669	0.014

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Plains	JAB&Reach	TN	PredatorTax	0.3	3.778	6.516	0.02
Plains	JAB&Reach	TN	CllctTax	0.411	0.697	1.732	0
Plains	JAB&Reach	TN	FiltrTax	0.567	1.176	3.311	0.019
Plains	JAB&Reach	TN	PredTax	0.3	3.761	5.513	0.021
Plains	JAB&Reach	TN	ScrapTax	0.944	1.427	1.818	0
Plains	JAB&Reach	TN	ShredTax	0.331	0.614	3.132	0.15
Plains	JAB&Reach	TN	TrchR300	0.438	1.121	1.758	0
Plains	JAB&Reach	TN	tTanypodPct	0.411	1.119	4.26	0.091
Plains	JAB&Reach	TN	tNonInsPct	0.352	1.065	5.033	0.155
Plains	JAB&Reach	TN	tCrusMolPct	0.375	1.049	6.516	0.115
Plains	JAB&Reach	TN	tOrth2MidgPct	0.362	0.725	3.591	0.053
Plains	JAB&Reach	TN	tFiltCollPct	0.467	1.335	3.591	0.018
Plains	JAB&Reach	TN	tEPTPct	0.915	1.361	3.21	0.001
Plains	JAB&Reach	TN	tPredPctM	0.283	1.895	4.417	0.123
Plains	JAB&Reach	TN	tEPTnoHBPct	0.942	1.486	3.884	0.002
Plains	JAB&Reach	TN	tMidgePct	0.317	1.087	4.988	0.089
Plains	JAB&Reach	TN	tShredPct	0.437	1.578	5.033	0.047
Plains	JAB&Reach	TN	tPredPctLV	0.301	1.642	4.417	0.123
Plains	JAB&Reach	TN	tCllctPct	0.317	1.321	5.154	0.112
Plains	JAB&Reach	TN	tFiltrPct	0.282	1.79	4.687	0.116
Plains	JAB&Reach	TN	tPredPct	0.29	1.704	3.895	0.121
Plains	JAB&Reach	TN	tScrapPct	0.399	1.305	2.987	0.001
Plains	JAB&Reach	TN	O.E_p.half	0.947	1.578	3.311	0
Plains	JAB&Reach	TP	MtnIndex	0.019	0.101	0.554	0.105
Plains	JAB&Reach	TP	LowValIndex	0.019	0.101	1.004	0.088
Plains	JAB&Reach	TP	PlainsIndex	0.018	0.187	0.828	0.302
Plains	JAB&Reach	TP	HBI	0.012	0.039	0.686	0.176
Plains	JAB&Reach	TP	ShredderTax	0.012	0.071	1.042	0.091
Plains	JAB&Reach	TP	EPTTax	0.031	0.079	0.255	0.012
Plains	JAB&Reach	TP	EphemTax	0.02	0.2	0.254	0.025
Plains	JAB&Reach	TP	PlecTax	0.012	0.025	0.572	0.204
Plains	JAB&Reach	TP	PredatorTax	0.008	0.309	1.281	0.013
Plains	JAB&Reach	TP	CllctTax	0.013	0.062	0.354	0.004
Plains	JAB&Reach	TP	FiltrTax	0.02	0.08	0.836	0.276
Plains	JAB&Reach	TP	PredTax	0.01	0.309	1.224	0.014
Plains	JAB&Reach	TP	ScrapTax	0.045	0.22	1.004	0.004
Plains	JAB&Reach	TP	ShredTax	0.012	0.071	1.004	0.091
Plains	JAB&Reach	TP	TrchR300	0.042	0.066	0.275	0.01
Plains	JAB&Reach	TP	tTanypodPct	0.012	0.488	1.004	0.121
Plains	JAB&Reach	TP	tNonInsPct	0.031	0.101	0.696	0.142
Plains	JAB&Reach	TP	tCrusMolPct	0.021	0.139	1.004	0.295

Region	methods	Nutrient	Metric	CP 10th	CP median	CP 90th	CP p
Plains	JAB&Reach	TP	tOrth2MidgPct	0.027	0.052	0.828	0.009
Plains	JAB&Reach	TP	tFiltCollPct	0.012	0.11	1.281	0.031
Plains	JAB&Reach	TP	tEPTPct	0.012	0.22	0.554	0.074
Plains	JAB&Reach	TP	tPredPctM	0.008	0.143	0.686	0.134
Plains	JAB&Reach	TP	tEPTnoHBPct	0.019	0.079	0.832	0.168
Plains	JAB&Reach	TP	tMidgePct	0.012	0.034	0.973	0.006
Plains	JAB&Reach	TP	tShredPct	0.037	0.578	1.224	0
Plains	JAB&Reach	TP	tPredPctLV	0.008	0.139	0.708	0.134
Plains	JAB&Reach	TP	tCllctPct	0.012	0.072	1.007	0.054
Plains	JAB&Reach	TP	tFiltrPct	0.015	0.35	0.442	0.017
Plains	JAB&Reach	TP	tPredPct	0.008	0.149	0.705	0.134
Plains	JAB&Reach	TP	tScrapPct	0.012	0.052	0.666	0.001
Plains	JAB&Reach	TP	O.E_p.half	0.028	0.095	0.781	0.007

Appendix D

Species Sensitivity Distribution

DEVELOPING NUTRIENT CRITERIA USING A SPECIES SENSITIVITY DISTRIBUTION APPROACH

Lei Zheng *

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Introduction

Species sensitivity distribution (SSD) approach has been used to develop water quality criteria since the early eighties (Posthuma et al. (3)). Initially, laboratory toxicity test detects responses (LC50) of a few species and these responses (sensitivities to toxicants) were then used to develop species sensitivity distribution.

Bioassessment programs have accumulated tons of species response data. These field observed datasets have the advantages: 1. Large dataset with lots of observations; 2. Hundreds of taxa were observed responding to various stressor gradients. 3. The criteria developed from this approach would be protective to individual taxon, not certain metrics or indices.

The disadvantages of field observation are also evidential:

1. Multiple stressors often exist concurrently;
2. Rare taxa (low capture probability, low abundance) could be an confounding factor
3. Systematic/random errors could be very large

Although we have to be cautious in applying the SSD approach to derive numeric criteria from field data, it is still a valuable way to develop nutrient end points and could be a very important line of evidence for criteria development.

Objectives

The main goal of this approach is to develop numeric nutrient criteria based on responses of macroinvertebrate taxa to nutrients. In order to use the SSD approach to develop numeric stressor criteria, I first examined the taxonomic responses to nutrient variables for each individual taxon. I used generalized additive model to develop the response curves of macroinvertebrate taxa along nutrient gradients, which could be unimodal, decreasing, increasing, and U-shaped (concave-up). I used both abundance and presence/absence data to examine the relationships. After the relationships were determined, I delineated taxon tolerance to nutrients with a number of approaches. Finally, based on the tolerance of each taxon, I compiled the cumulative distribution function from all observed taxa and established numeric criteria from the taxa tolerance distribution.

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Methods

I used Montana's macroinvertebrate nutrient datasets to analyze the nutrient thresholds. Ben Jessup used a 30-day window to associate macroinvertebrates and nutrient samples and nutrient variables were avearged if samples were taken within 30 day window. Macroinvertebrate samples were rarified to 300 organisms. Existing OTUs were used to reduce the data. Conductivity, pH, and temperature samples were also imported and matched with nutrient and benthic samples. About 1081 samples, collected from 1033 stations using 5 different methods were found with matched macroinvertebrate and chemistry variables. The table below shows different sampling methods in each of the three site classes and seven ecoregions.

I considered a number of factors that might affect our decisions to determine nutrient criteria. These factors include:

- Regions: Site Classes vs. ecoregion
- Data selection: full dataset vs. partitioned out other stressors
- Data Type: presence/absence vs. abundance
- Taxa list: all taxa occurring in at least 30 sites, sensitive taxa occurring in at least 30 sites, and taxa occurring in reference sites

Regions

I used bioregions/site classes instead of ecoregions for this analysis for several reasons. First, biological response should be strictly according to biological region classification. Second, the SSD approach requires large sample size (at least 20 occurence for each taxon) so most of the ecoregion would not have enough taxa to perform the analysis. Second, I intended to use reference taxa list to derive nutrient criteria. The reference taxa in Middle Rockies region (the only ecoregion has a large sample size) is significantly different from Low Valley region in the same ecoregion due to elevation and temperature differences.

For demonstration purpose, I plotted only samples from the Mountain region. Results from other regions were shown in the final tables.

Data partition

Several potential co-varaibles along with nutrient stressors we are particularly concerned are conductivity, pH, sulfate, chloride, and several metals (e.g., Se, Fe, Al, Mn). Habitat scores may be another co-virable affecting the response of macroinvertebrates to nutrients. From our previous study, conductivity seems most strongly correlated with biological degradation as well as nutrients. Therefore, I limited the conductivity to the 95th percentile of reference conducvitiy values (300 μS/cm) and pH to 8.5. For comparison purposes, I used all data, as well as partitioned data to separate other stressors from the one stressor of interest.

Taxon response

A common assumption for taxon-environment relationships is that the distribution of a particular taxon is unimodal with respect to environmental gradients. This relationship, along with other simpler linear responses (decreasing or increasing), are the most commonly observed patterns in field observation data. However, these relationships can't be applied to all taxa so a generalized additive regression using standard max-

Table 1: Number of samples using different methods and in different regions.

	Class	HESS	JAB	KICK	ReachWide	TarRiff
1	Canadian Rockies	5	0	13	3	6
2	Idaho Batholith	0	0	31	0	2
3	Middle Rockies	15	6	354	10	36
4	Northern Rockies	8	3	112	0	13
5	NW Glaciated Plains	7	41	78	21	16
6	NW Great Plains	11	90	137	37	14
7	Wyoming Basin	0	2	5	0	0
8	Low Valleys	14	1	181	5	7
9	Mountains	19	8	360	9	42
10	Plains	13	133	189	57	25

imum likelihood estimation can be used to fit the curve (Yuan 2006)(5). Here, the distribution of a given taxon is modeled as follows:

$$\left(\frac{p}{1-p}\right) = S_0 + S(x) \tag{1}$$

where p is the probability of capturing a taxon, and S_0 is the constant of the nonparametric model and S(x) represents a nonparametric smooth curve that is fit through the data. The nonparametric responses have the potential to capture smaller scale variations in response. The left side of the equation is the logit ratio of the capture probability.

After a taxon-stressor relationship is modeled, I classified the response curve shape to unimodal, decreasing, increasing, and concave-up shapes using a statistic test(1). I only modeled taxa that were present (for rare taxa) or absent (for extremly common taxa) in at least 30 sites in the dataset to develop the GAM models. I developed R codes based on the idea of Lester Yuan's bio.infer package (Yuan et al. 2009)(6) to generate taxon environmental plots and tolerance values.

Taxon tolerances

I used three different approaches to determine taxon tolerance values. First, I determined the highest observed stressor values where a macroinvertebrate taxon was captured, and used the 95th percentile of that higest observed value as the taxa tolerance value. The 95th percentile of the observed stressor value is likely a better representation of taxon tolerance than the maximum value since it takes into account sampling error in the data.

Second, I also used taxon abundance data (relative abundance) to calculate taxon tolerance values to nutrients. The empirical cumulative percentile (CP) approach estimates a CP value for a given value of the environmental variable (x_0), and the tolerance value is the abundance weighted cumulative percentile:

$$CP(x_0) = \frac{\sum_{i=1}^{N} Y_{ij} I(x_i < x_0)}{\sum_{i=1}^{N} Y_{ij}} \tag{2}$$

where N is the total number of sites and x_i is the value of the environmental variable of interest at site I, Y_{ij} is the abundance of species j at site I,

$I = 1$ if $x_i < x_0$ and $I = 0$ if $x_i \geq x_0$. In order to estimate the maximum level of a stress under which a taxon could persist/tolerate, I fixed the CP to 0.95.

Finally I generated tolerance values from the modeled response curve. A 95% cumulative probability probability was used as tolerance value.

In the final results, I only presented the third approach, which is 95% cumulative probability of the GAM models since it is the most robust approach.

Nutrient Criteria

After the tolerance values of macroinvertebrate taxa were developed from various approaches, a selected list of taxa were used to generate an empirical distribution function. The 5th percentiles of the cumulative frequency were considered the potential criteria to protect 95% of the taxa.

Results

The probability of occurence of *Acentrella* responded to both TN and TP gradients (Figure 1). *Acentrella* presents almost linear decreasing response to elevated TP concentrations and a unimodal response to TN concentrations.

I showed three ways to present the SSD: 95th cumulative percentile tolerance from abundance (CP95), 95th percentile of maximum observed stressor value(95thMax), and GAM model derived tolerance values (Model95) to represent taxon tolerance to environmental stressors. The cumulative distribution frequency of these tolerance values (Figure 2) and their 5th percentiles of the cumulative frequency distribution were considered the potential criteria to protect 95% of the taxa.

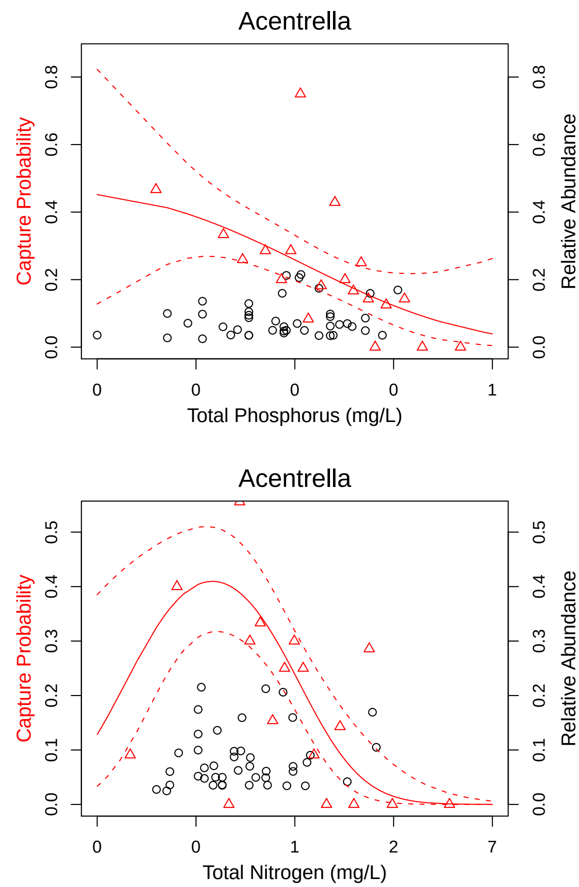

Figure 1: Examples of *Acentrella* response to nutrient gradients. The black circles represent the relative abundance of that taxon in a site. The red triangle represents capture probability of individual taxon at a particular range of conductivity. The red fitted lines are the mean model fit and its 90% confidence intervals of the capture probability.

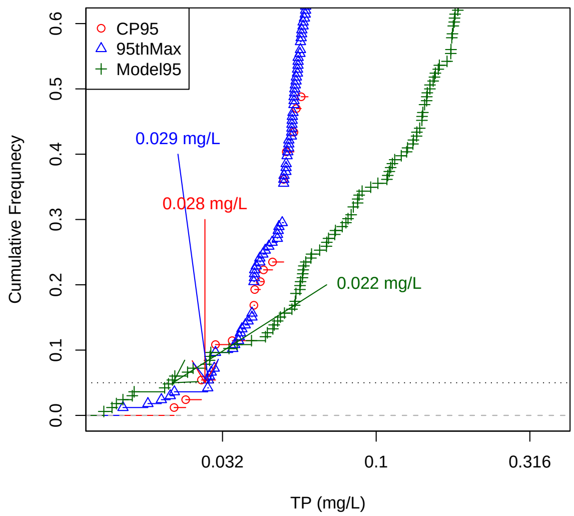

Figure 2: Cumulative frequency distribution of macroinvertebrate sensitivity to the TP gradient when other stressors were excluded. The 95th cumulative percentile tolerance from abundance (CP95), 95th percentile of maximum observed stressor value (95thMax), and persence/absence based generalized additive model derived tolerance values (Model95) were used to derive the cumulative frequency curves.

After taxa occurred in at least 30 sites were modeled, two selected taxa lists were used to generate SSD and to derive nutrient criteria. First, I selected taxa that occured only in reference stations. Criteria developed from this list is intended to protect 95% of reference taxa. The model derived TP value (model95), the maximum observed value (95Max) (0.022 and 0.029 mg/L respectively) are similar to the abundance based CP95 value (0.028 mg/L) (as shown in Figure 2).

Second, I generated a sensitive taxa list based on taxon response curve, where taxa shown "decreasing" or "unimodal" responses to stressors were included in this list as our protected taxa. This approach generated slightly lower nutrient criteria.

Table 2: Numeric TN and TP criteria derived from the taxon sensitivity distribution approach using partitioned data, Ref - Taxa occured in reference sites, Sensitive - Sensitive taxa occurred in at least 30 sites

	Groups	Ref	Sensitive
	Total Nitrogen (mg/L)		
1	LowValley_KICK	1.159	0.835
2	Mountains_KICK	0.446	0.377
3	Plains_JAB	3.27	3.015
4	Plains_KICK	0.937	0.828
	Total Phosphorus (mg/L)		
5	LowValley_KICK	0.059	0.045
6	Mountains_KICK	0.022	0.016
7	Plains_JAB	0.455	0.462
8	Plains_KICK	0.077	0.063

I have used partioned datasets and the full dataset, and two different taxa lists to examine taxon sensitivity distribution and to further derive different criteria (Table 2, 3). The numeric stressor criteria developed from this approach was calculated based on the model95 tolerances.

Discussion

I was surprised to see quite different TN and TP criteria developed from the SSD approach using different sampling methods in the Plains (Table **??**). To verify that cause, I plotted EPT

Table 3: Numeric TN and TP criteria derived from the taxon sensitivity distribution approach without data partition; Ref - Taxa occured in reference sites, Sensitive - Sensitive taxa occurred in at least 30 sites

	Groups	Ref	Sensitive
	Total Nitrogen (mg/L)		
1	LowValley_KICK	1.034	0.926
2	Mountains_KICK	0.438	0.405
3	Plains_JAB	5.395	3.243
4	Plains_KICK	0.895	0.796
	Total Phosphorus (mg/L)		
5	LowValley_KICK	0.053	0.046
6	Mountains_KICK	0.023	0.016
7	Plains_JAB	0.57	0.508
8	Plains_KICK	0.075	0.063

taxa *vs* TP using two different sampling methods in the Plains (Figure 3). It is quite obvious from these graphs that TP concentrations were significantly higher in streams sampled with JAB and reachwide methods than streams sampled with kick and target riffle methods. If a criterion is expected to develop from the metric response, the criteria would be different as well based on these collection methods.

One of the by-prodcuts of this analysis is that we developed taxon tolerance values for each of stressor variables using three different approaches (Weighted averaging, 95th percentile of cumulative frequency distribution, and maximum likelihood estimates) using both the full dataset and the partitioned dataset. The three approaches (especially between WA and CP95 and MLE models) generated different optima values (Figure 4) but generally they were correlated.

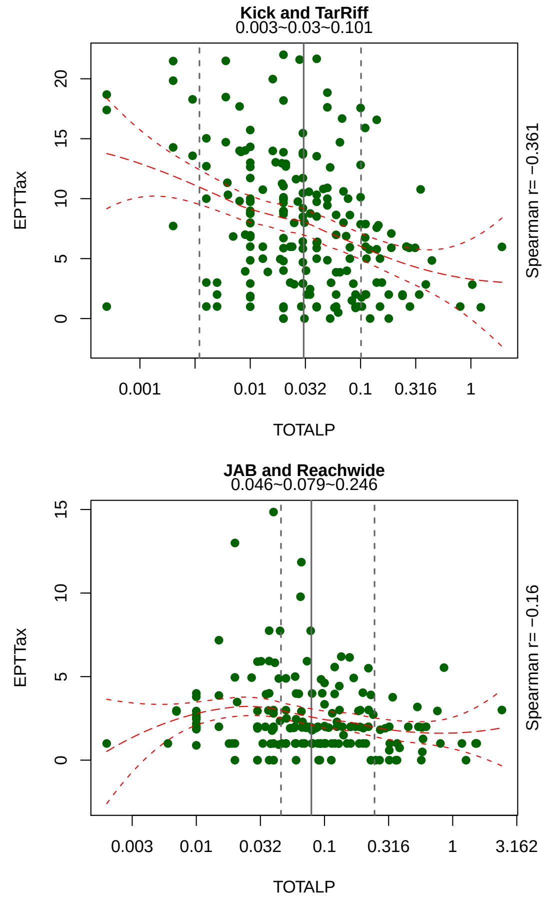

Figure 3: Response of Number of EPT taxa to TP gradient in the Plains

Disclaims

This documet presented a statistical approach to derive nutrient endpoints for Montana's streams, which has not been approved by EPA. The results of this analysis is preliminary and may not represent the most accurate estimate of nutrient endpoints in each region.

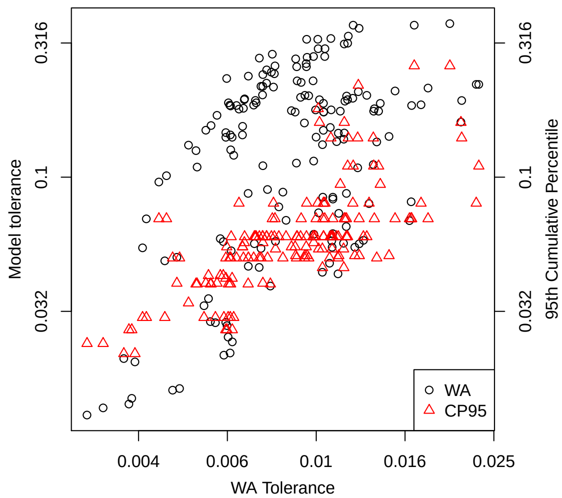

Figure 4: Comparisons of weighted averaging optima, 95th cumulative percentile tolerance, and maximum likelihood (model) optima values for total phosphorus

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Appendix E

Periphyton change-point analysis

Table E-1. Statistics from periphyton change-point analysis.

Ecoregion	Metric	Nutrient	ci 0.025	CP median	Ci 0.975	CP p
16	pi_Ptpv_TN_all_Lo	TN	0.057	0.147	0.285	0.511
16	pi_Ptpv_TN_CWP_Lo	TN	0.097	0.285	0.452	0.005
16	pi_Ptpv_TN_WM_Lo	TN	0.059	0.106	0.285	0.5
16	pi_Diatas_TP_1	TP	0.006	0.007	0.014	0.015
16	pi_Ptpv_TP_all_Lo	TP	0.001	0.003	0.014	0.006
16	pi_Ptpv_TP_CWP_Lo	TP	0.001	0.003	0.014	0.003
16	pi_Ptpv_TP_WM_Lo	TP	0.001	0.003	0.014	0.009
16	pi_IncMtnNut	TP	0.003	0.003	0.014	0.041
16	pi_Trophic_56	TP	0.001	0.003	0.014	0.034
16	wa_OptCat_NutMMI	TP	0.001	0.005	0.014	0.022
16	wa_MAIATSIC	TP	0.001	0.003	0.009	0.009
16	wa_OptCat_DisTotMMI	TP	0.001	0.014	0.014	0.024
16	wa_Poll_Tol	TP	0.001	0.005	0.014	0.056
16	x_Kelly_TDI	TP	0.001	0.005	0.014	0.179
17	pi_Ptpv_TN_all_Lo	TN	0.057	0.33	1.665	0.082
17	pi_Ptpv_TN_CWP_Lo	TN	0.107	0.515	1.324	0.012
17	pi_Ptpv_TN_WM_Lo	TN	0.057	0.307	1.274	0.08
17	pi_Diatas_TP_1	TP	0.021	0.038	0.285	0
17	pi_Ptpv_TP_all_Lo	TP	0.003	0.017	0.029	0
17	pi_Ptpv_TP_CWP_Lo	TP	0.001	0.005	0.026	0
17	pi_Ptpv_TP_WM_Lo	TP	0.001	0.016	0.029	0
17	pi_IncMtnNut	TP	0.001	0.012	0.039	0.016
17	pi_Trophic_56	TP	0.008	0.027	0.062	0
17	wa_OptCat_NutMMI	TP	0.011	0.021	0.029	0
17	wa_MAIATSIC	TP	0.009	0.025	0.028	0
17	wa_OptCat_DisTotMMI	TP	0.011	0.021	0.031	0
17	wa_Poll_Tol	TP	0.004	0.029	0.25	0
17	x_Kelly_TDI	TP	0.006	0.021	0.039	0
15	pi_Ptpv_TN_all_Lo	TN	0.075	0.265	0.779	0.245
15	pi_Ptpv_TN_CWP_Lo	TN	0.057	0.107	0.89	0.07
15	pi_Ptpv_TN_WM_Lo	TN	0.05	0.25	0.779	0.244
15	pi_Diatas_TP_1	TP	0.014	0.028	0.03	0
15	pi_Ptpv_TP_all_Lo	TP	0.004	0.013	0.026	0.001

Ecoregion	Metric	Nutrient	ci 0.025	CP median	Ci 0.975	CP p
15	pi_Ptpv_TP_CWP_Lo	TP	0.004	0.007	0.028	0.008
15	pi_Ptpv_TP_WM_Lo	TP	0.004	0.004	0.028	0.002
15	pi_IncMtnNut	TP	0.007	0.029	0.039	0
15	pi_Trophic_56	TP	0.005	0.029	0.034	0
15	wa_OptCat_NutMMI	TP	0.005	0.017	0.029	0
15	wa_MAIATSIC	TP	0.005	0.028	0.034	0.001
15	wa_OptCat_DisTotMMI	TP	0.005	0.017	0.029	0
15	wa_Poll_Tol	TP	0.004	0.009	0.036	0.111
15	x_Kelly_TDI	TP	0.001	0.005	0.029	0.089
42	pi_Ptpv_TN_all_Lo	TN	0.094	0.28	2.088	0.011
42	pi_Ptpv_TN_CWP_Lo	TN	0.831	0.965	1.687	0.011
42	pi_Ptpv_TN_WM_Lo	TN	0.094	0.172	0.331	0
42	pi_Diatas_TP_1	TP	0.006	0.023	0.173	0.002
42	pi_Ptpv_TP_all_Lo	TP	0.003	0.007	0.054	0
42	pi_Ptpv_TP_CWP_Lo	TP	0.003	0.007	0.11	0
42	pi_Ptpv_TP_WM_Lo	TP	0.003	0.017	0.049	0
42	pi_IncMtnNut	TP	0.009	0.009	0.012	0.037
42	pi_Trophic_56	TP	0.006	0.012	0.054	0
42	wa_OptCat_NutMMI	TP	0.006	0.017	0.044	0
42	wa_MAIATSIC	TP	0.003	0.007	0.028	0
42	wa_OptCat_DisTotMMI	TP	0.006	0.02	0.059	0
42	wa_Poll_Tol	TP	0.006	0.023	0.209	0.007
42	x_Kelly_TDI	TP	0.003	0.007	0.084	0.001
43	pi_Ptpv_TN_all_Lo	TN	0.192	0.341	0.627	0
43	pi_Ptpv_TN_CWP_Lo	TN	0.056	0.692	0.859	0.001
43	pi_Ptpv_TN_WM_Lo	TN	0.137	0.299	0.417	0
43	pi_Diatas_TP_1	TP	0.028	0.036	0.145	0
43	pi_Ptpv_TP_all_Lo	TP	0.006	0.007	0.011	0
43	pi_Ptpv_TP_CWP_Lo	TP	0.007	0.008	0.022	0
43	pi_Ptpv_TP_WM_Lo	TP	0.006	0.008	0.01	0
43	pi_Trophic_56	TP	0.006	0.008	0.069	0
43	wa_OptCat_NutMMI	TP	0.006	0.011	0.063	0
43	wa_MAIATSIC	TP	0.006	0.007	0.205	0
43	wa_OptCat_DisTotMMI	TP	0.006	0.011	0.098	0
43	wa_Poll_Tol	TP	0.008	0.029	0.145	0
43	x_Kelly_TDI	TP	0.005	0.007	0.027	0